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GEORGIA INSTITUTE OF TECHNOLOGY
OFFICE OF RESEARCH ADMINISTRATION

RESEARCH PROJECT INITIATION

Date: May 21, 1975

Project Title: Measure of Radio Meteor Winds

Project No: E-16-668

Principal Investigator Dr. R. G. Roper

Sponsor: National Science Foundation

Agreement Period: From 6/1/75 Until 11/30/76*

* 12 month budget period plus 6 months for submission of required reports, etc.

Type Agreement: Grant No. DES75-14414

Amount: $29,200 NSF
1,537 GIT (E-16-358)
$30,737 Total

Reports Required: Annual Letter Technical; Final Report

Sponsor Contact Person (s):

Administrative Matters
thru ORA
Mr. Gaylord L. Ellis
Grants Officer
National Science Foundation
Washington, D. C. 20550
(202) 632-5965

Assigned to: Aerospace Engineering

COPIES TO:

Principal Investigator
School Director
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Project File
Other

RA-3 (6-71)

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GEORGIA INSTITUTE OF TECHNOLOGY
OFFICE OF CONTRACT ADMINISTRATION

SPONSORED PROJECT TERMINATION

Date: 12/15/78

Project Title: Measure of Radio Meteor Winds

Project No: E-16-668

Project Director: R. G. Roper

Sponsor: National Science Foundation

Effective Termination Date: 11/30/78

Clearance of Accounting Charges: 11/30/78

Grant/Contract Closeout Actions Remaining:

TERMINATED

- _ Final Invoice and Closing Documents
- X Final Fiscal Report (See Important Notice No. 68)
- _ Final Report of Inventions
- _ Govt. Property Inventory & Related Certificate
- _ Classified Material Certificate
- _ Other ____________

Assigned to: Aerospace Engineering (School/Laboratory)

COPIES TO:

Project Director
Division Chief (EES)
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Director, Physical Plant
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Project File (OCA)
Project Code (GTRI)
Other ____________

CA–4 (3/76)

E-16-668

GEORGIA INSTITUTE OF TECHNOLOGY

ATLANTA, GEORGIA 30332

SCHOOL OF
AEROSPACE ENGINEERING

DANIEL GUGGENHEIM SCHOOL
OF AERONAUTICS

~~XXXXXXXXXX~~
404-894-3014

March 26, 1976

Dr. Gene W. Adams
Atmospheric Sciences
NSF, Room 312
1800 G Street NW
Washington, DC 20550

Subject: Continuation of Grant
No. DES75-14414

Dear Gene:

I am pleased to be able to report that the first year of operation of the Georgia Tech Radio Meteor Wind Facility under the above grant has exceeded the expectations proposed. Operation of the facility has been almost continuous, with no serious gaps in the data. Weekly means of prevailing winds, diurnal and semidiurnal tides for the height range 80 to 100 km above Atlanta have been calculated, and are in the process of being documented in a report which will cover the period August 1974 through March 1975, with a six week gap in April-May 1975 which was eventually traced to a tape recorder malfunction.

While not a part of this grant, funds received from NSF through AGU helped in my being able to attend the XVIth General Assembly of the IUGG in Grenoble last summer. Of particular relevance to this current contract was the URSI/IAGA sponsored workshop on Cooperative Tidal Observations in the Lower Thermosphere. With the exception of four stations operated by the Hydrometeorological Service of the USSR, the Georgia Tech facility is the only one in the world achieving anything close to continuous operation. Thus the scheduling of cooperative observational periods is extremely important. The results of the First Cooperative Experiment (August 9-14, 1974) were reviewed in Grenoble. The global nature of the observed semidiurnal oscillation was obvious in the data, while the unstable nature of the diurnal tide in the lower thermosphere was confirmed. Further evidence for synoptic scale structure in the "prevailing" component was also forthcoming.

In addition to coordinated observations carried out in October '75, a concerted effort was made to have as much data as possible gathered during January '76, for comparison with rocket data obtained by the Wallops Island Winter Anomaly Program, and a similar European rocket effort mounted in Spain. I am spearheading a move to have published by fall the results of the three cooperative experiments to date, together with a short writeup on the equipment used by each of the stations participating. I believe such a collection of papers published simultaneously in one journal will be of great value.

Two Ph.D. students are currently being supported by the contract. P. M. Dolas is working on tidal motions as measured by the Georgia Tech Radio Meteor Wind Facility, and on the interpretation of the observed changed in lower thermospheric circulation associated with polar stratospheric warmings. M. L. Salby is furthering the spectral analysis of meteor wind data, with particular emphasis being placed on planetary waves and synoptic scale disturbances in the "prevailing" wind. Both anticipate submitting their theses in 1977.

A program of collaboration with the University of Illinois and the University of New Hampshire, designed to better the understanding of the lower thermospheric circulation over the eastern United States, is proceeding.

A concerted effort is being made to ensure the continuous operation of the Georgia Tech Meteor Wind Facility, and the data gathered will continue to be made available to the scientific community, and the Global Radio Meteor Wind Studies Project of IAGA in particular. The avenues of communication with the Incoherent Scatter technique established through the URSI/IAGA Cooperative Tidal Observations will be further strengthened. I see no reason why aims of my original proposal for the period 1976-1977 should not be attained.

I am enclosing a copy of the proposed budget on DES75-14414 for the year June 1, 1976 - May 31, 1977, as included in my original submission.*

Yours sincerely,

Dr. R. G. Roper, Associate Professor
School of Aerospace Engineering
Chairman, IAGA Division V, W. G. 2
(Meteor Observatories)

RGR/ad

*Total budget remains unchanged. Minor changes in categories have been made due to changes in approved Retirement Benefits and Indirect Costs.

ENDORSEMENT:

NOTE: At this time it is estimated that there will be no remaining funds at the end of the period for which NSF currently is providing support.

for Edward E. Renfro, Director
Office of Contract Administration

E-16-668

AFGL-TR-76-0063

CHEMICAL RELEASE TRIANGULATION AND WINDS IN THE ALTITUDE RANGE 93 KM TO 176 KM, OCTOBER 1973 AND JUNE 1974

Robert G. Roper
Howard D. Edwards

Georgia Institute of Technology
School of Aerospace Engineering
Atlanta, Georgia 30332

March 1976

Scientific Report No. 2

Approved for public release; distribution unlimited

AIR FORCE GEOPHYSICS LABORATORIES
AIR FORCE SYSTEMS COMMAND
UNITED STATES AIR FORCE
HANSCOM AFB, MASSACHUSETTS 01731

CLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER AFGL-TR-76-0063	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
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7. AUTHOR(s) Robert G. Roper Howard D. Edwards		8. CONTRACT OR GRANT NUMBER(s) F-19628-74-C-0085
9. PERFORMING ORGANIZATION NAME AND ADDRESS Georgia Institute of Technology School of Aerospace Engineering Atlanta, GA 30332		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS 62101F 763514
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17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

Tech Other

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Upper Atmospheric Release Data

Rocket Wind Data

Wind Data

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Chemical release position data and wind profiles from three rockets have been computed and tabulated. The position data is for use in subsequent analysis of spectral records of chemical reaction radiance intensities.

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

TABLE OF CONTENTS

EXPLANATION OF THE TABLES

This report is divided into two sections. The first deals with the reduction and tabulation of chemical release position data, which is used subsequently by AFGL personnel in the interpretation of spectral energy measurements which they have made of the releases. The second section treats the tabulation and plotting of data delineating neutral wind motions.

Tables are presented which give the position, and the time history, of the centers of puffs of vaporized chemicals released by three rockets in the lower thermosphere. Two of these, plus an additional trail release have been further reduced, to produce both tables and graphs of the variation of wind speed with altitude.

Negative wind and shear components indicate winds and shears toward the south and west. Wind headings are given in degrees east of north. Vertical winds are in meters/sec., and are positive upwards.

SITE ONE [1] IS TYNDALL**SITE TWO [2, IS CRESTVIEW**SITE THREE [3] IS PENSACOLA .

1. CODE N EQUAL 4, POINT POSITION DATA
2. SERIES CODE, YEAR TO ONE DECIMAL DIGIT
3. ROCKET CODE NUMBER
4. TWO SITES PAIRED FOR TRIANGULATION , A IS THE BASE SITE
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1	2	3	4		5	6	7	8	9	10	11	12
			SITES		TIME		HEIGHT	LATITUDE	LONGITUDE	RANGE	RANGE	RESIDUAL
N	YEAR	RKT	A	B	SEC	PT	KM	DEG.(N)	DEG.(W)	A, KM	B, KM	RADIANS
4	73.8	3	1	2	896	400	94.90	29.2294	86.2725	148.36	198.07	0.00 20
4	73.8	3	1	2	912	400	93.83	29.2357	86.2664	146.96	197.03	0.00085
4	73.8	3	1	2	927	400	93.82	29.2268	86.2710	147.75	197.82	0.00079
4	73.8	3	1	2	942	400	93.40	29.2236	86.2607	147.16	198.08	0.00195
4	73.8	3	1	2	957	400	93.11	29.2254	86.2640	147.02	197.70	0.00245
4	73.8	3	1	2	972	400	92.75	29.2232	86.2714	147.32	197.64	0.00269
4	73.8	3	1	2	987	400	93.17	29.2133	86.2750	148.40	198.75	0.00375
4	73.8	3	1	2	1002	400	93.52	29.1981	86.2758	149.63	200.38	0.00445
4	73.8	3	1	2	1017	400	94.11	29.1821	86.2807	151.30	202.16	0.00428
4	73.8	3	1	2	1032	400	93.64	29.1792	86.2826	151.29	202.20	0.00420
4	73.8	3	1	2	1046	400	94.45	29.1610	86.2893	153.33	204.27	0.00411
4	73.8	3	1	2	1061	400	93.90	29.1624	86.2885	152.85	203.88	0.00369
4	73.8	3	1	2	1076	400	94.21	29.1527	86.2931	153.93	204.92	0.00377
4	73.8	3	1	2	1091	400	93.96	29.1475	86.3013	154.54	205.20	0.00294
4	73.8	3	1	2	1106	400	94.17	29.1346	86.2981	155.37	206.61	0.00417
4	73.8	3	1	2	1121	400	93.81	29.1327	86.3007	155.41	206.60	0.00463
4	73.8	3	1	2	1136	400	93.71	29.1258	86.3036	155.96	207.19	0.00383
4	73.8	3	1	2	1151	400	93.76	29.1235	86.3084	156.40	207.39	0.00427
4	73.8	3	1	2	1167	400	93.07	29.1170	86.3050	156.24	207.74	0.00401
4	73.8	3	1	2	1181	400	93.87	29.1077	86.3130	157.77	208.94	0.00358
4	73.8	3	1	2	1196	400	93.34	29.1058	86.3209	157.99	208.79	0.00297
4	73.8	3	1	2	1211	400	93.96	29.0840	86.3188	159.75	211.25	0.00406
4	73.8	3	1	2	1226	400	93.65	29.0901	86.3297	159.70	210.38	0.00333

SITE ONE [1] IS WALLOPS**SITE TWO [2] IS BACK BAY**SITE THREE [3] IS COQUINA

1. CODE N EQUAL 4, POINT POSITION DATA
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1	2	3	4		5	6	7	8	9	10	11	12
			SITES		TIME		HEIGHT	LATITUDE	LONGITUDE	RANGE	RANGE	RESIDUAL
N	YEAR	RKT	A	B	SEC	PT	KM	DEG.(N)	DEG.(W)	A, KM	B, KM	RADIANS
4	74.5	4	1	2	341	40	116.35	36.5339	73.8732	236.48	220.52	0.01351
4	74.5	4	1	2	356	40	111.28	36.4982	73.8270	239.05	221.86	0.00717
4	74.5	4	1	2	371	40	111.21	36.4913	73.8264	239.53	221.95	0.00490
4	74.5	4	1	2	386	40	110.90	36.4847	73.8225	240.07	222.19	0.00721
4	74.5	4	1	2	401	40	111.53	36.4752	73.8157	241.43	223.18	0.00660
4	74.5	4	1	2	416	40	111.89	36.4666	73.8104	242.51	223.91	0.00761
4	74.5	4	1	2	431	40	111.79	36.4617	73.8109	242.80	223.90	0.00602
4	74.5	4	1	2	341	42	105.35	36.4845	73.8045	238.50	220.82	0.00696
4	74.5	4	1	2	356	42	108.81	36.4987	73.8024	239.77	222.61	0.00529
4	74.5	4	1	2	371	42	107.96	36.4986	73.7895	240.11	223.19	0.00716
4	74.5	4	1	2	386	42	108.00	36.4901	73.7830	240.54	223.73	0.00770
4	74.5	4	1	2	401	42	108.03	36.4871	73.7671	241.67	225.04	0.00747
4	74.5	4	1	2	416	42	108.82	36.4837	73.7579	242.80	226.19	0.00708
4	74.5	4	1	2	431	42	109.33	36.4766	73.7412	244.49	227.86	0.00968
4	74.5	4	1	2	356	43	106.12	36.4859	73.7981	239.11	221.68	0.00564
4	74.5	4	1	2	371	43	104.05	36.4831	73.8035	238.06	220.28	0.00658
4	74.5	4	1	2	386	43	104.13	36.4860	73.8059	237.75	220.09	0.00566
4	74.5	4	1	2	401	43	104.08	36.4871	73.8073	237.57	219.94	0.00498
4	74.5	4	1	2	416	43	103.89	36.4899	73.8132	236.94	219.34	0.00489
4	74.5	4	1	2	431	43	103.72	36.4928	73.8167	236.46	218.94	0.00445
4	74.5	4	1	2	356	44	103.67	36.4776	73.7953	238.75	220.83	0.00363
4	74.5	4	1	2	371	44	102.47	36.4803	73.7988	237.81	219.93	0.00589
4	74.5	4	1	2	386	44	101.84	36.4847	73.8020	237.03	219.31	0.00338
4	74.5	4	1	2	401	44	101.74	36.4895	73.8097	236.20	218.58	0.00422
4	74.5	4	1	2	416	44	101.09	36.4985	73.8245	234.42	216.97	0.00344
4	74.5	4	1	2	431	44	101.30	36.5015	73.8203	234.54	217.37	0.00379
4	74.5	4	1	2	401	45	99.04	36.4940	73.7739	236.74	220.09	0.00429
4	74.5	4	1	2	416	45	98.87	36.5059	73.7801	235.45	219.35	0.00576
4	74.5	4	1	2	431	45	99.07	36.5141	73.7741	235.30	219.82	0.00489

SITE ONE (1) IS WALLOPS**SITE TWO (2) IS BACK BAY**SITE THREE (3) IS COQUINA

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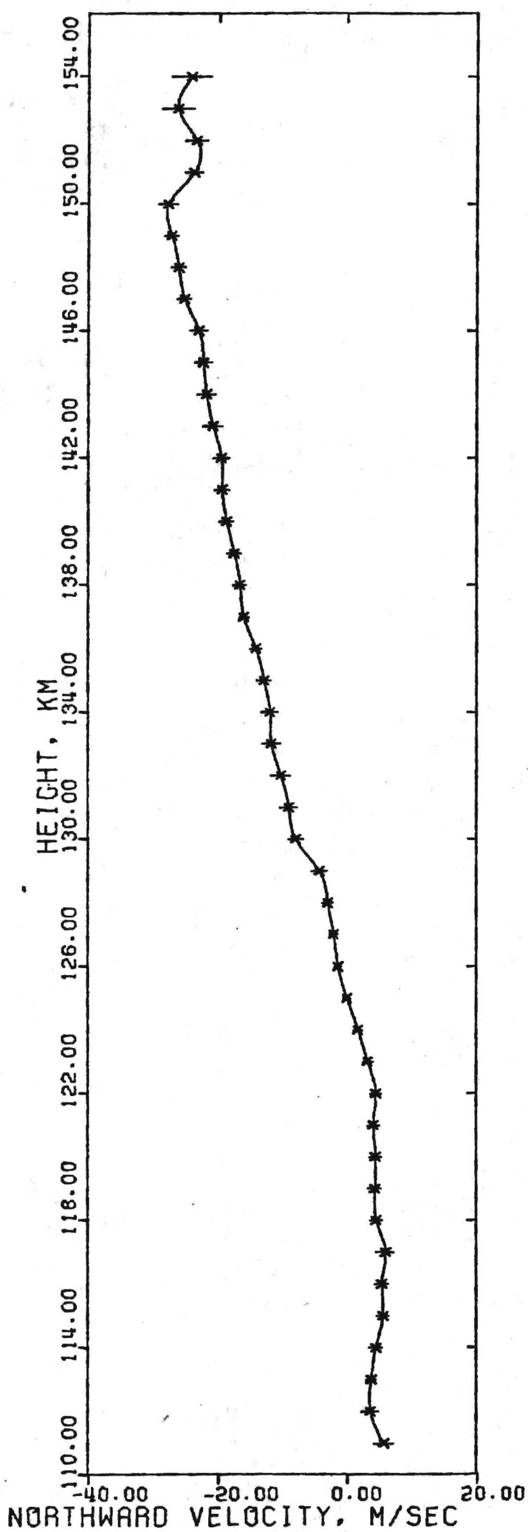
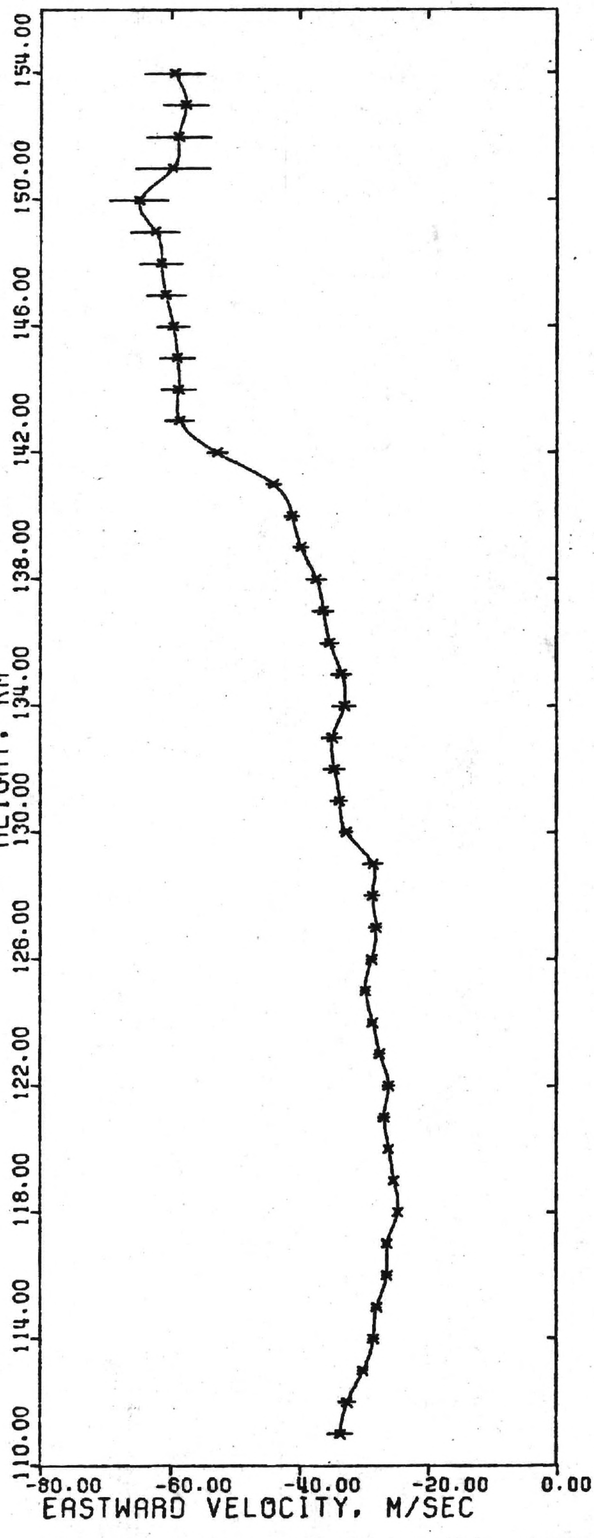
			SITES		TIME		HEIGHT	LATITUDE	LONGITUDE	RANGE	RANGE	RESIDUAL
N	YEAR	RKT	A	B	SEC	PT	KM	DEG.(N)	DEG.(W)	A, KM	B, KM	RADIANS
4	74.5	2	1	3	669	10	176.28	37.1570	75.2281	193.94	231.50	0.00234
4	74.5	2	1	3	684	10	176.04	37.1500	75.2344	193.97	230.74	0.00348
4	74.5	2	1	3	693	10	176.78	37.1499	75.2498	194.50	231.14	0.00492
4	74.5	2	1	3	699	10	175.16	37.1257	75.2595	194.05	228.06	0.00042
4	74.5	2	1	3	714	10	175.70	37.1130	75.2578	195.15	227.60	0.00193
4	74.5	2	1	3	684	11	164.92	37.1207	75.2166	185.52	220.39	0.00268
4	74.5	2	1	3	693	11	164.67	37.1132	75.2213	185.61	219.60	0.00392
4	74.5	2	1	3	699	11	165.02	37.1097	75.2280	186.02	219.52	0.00286
4	74.5	2	1	3	714	11	165.06	37.0991	75.2396	186.47	218.64	0.00301
4	74.5	2	1	3	729	11	164.42	37.0910	75.2530	186.17	217.41	0.00370
4	74.5	2	1	3	693	12	156.06	37.0977	75.2067	178.97	212.22	0.00351
4	74.5	2	1	3	699	12	155.72	37.0937	75.2104	178.84	211.61	0.00429
4	74.5	2	1	3	714	12	155.36	37.0819	75.2236	178.99	210.30	0.00452
4	74.5	2	1	3	729	12	155.45	37.0727	75.2376	179.41	209.51	0.00540
4	74.5	2	1	3	699	13	146.40	37.0742	75.1974	172.00	203.51	0.00461
4	74.5	2	1	3	714	13	146.18	37.0660	75.2083	172.14	202.57	0.00403
4	74.5	2	1	3	729	13	146.04	37.0572	75.2108	172.49	201.76	0.00848
4	74.5	2	1	3	714	14	135.93	37.0517	75.1898	164.58	194.42	0.00527
4	74.5	2	1	3	729	14	135.74	37.0492	75.1928	164.53	194.04	0.00630

CODE NAME.. PRE-ALLADIN LAUNCH DATE.. 6/28/74 TIME.. 2110 EDT

HEIGHT (KM)	SPEED (M/S)	HEADING (DEG)	N-S WIND (M/S)	E-W WIND (M/S)	N-S SHEAR (M/S/KM)	E-W SHEAR (M/S/KM)
******	*****	*******	********	********	*********	*********
111	34	280	6	-34	-3	1
112	33	276	4	-33	-1	2
113	30	277	4	-30	1	2
114	29	279	5	-28	1	1
115	29	281	6	-28	0	1
116	27	282	5	-26	0	1
117	27	283	6	-26	0	1
118	25	280	5	-25	-1	1
119	26	280	4	-25	0	-1
120	27	280	4	-26	0	-1
121	27	279	4	-27	0	0
122	27	280	5	-26	0	0
123	28	277	3	-28	-2	-2
124	29	273	2	-29	-2	-1
125	30	270	0	-30	-2	0
126	29	267	-1	-29	-1	1
127	28	266	-2	-28	-1	0
128	29	264	-3	-29	-1	0
129	29	261	-4	-29	-3	-2
130	34	256	-8	-33	-3	-3
131	35	255	-9	-34	-1	0
132	36	254	-10	-35	-2	-1
133	37	251	-12	-35	-1	1
134	35	250	-12	-33	0	1
135	36	249	-13	-34	-1	-2
136	38	248	-14	-35	-2	-2
137	40	246	-16	-36	-1	-1
138	41	246	-17	-37	-1	-2
139	44	246	-18	-40	-1	-2
140	45	246	-19	-41	-1	-1
141	48	246	-19	-44	0	-6
142	56	250	-20	-53	-1	-9
143	62	250	-21	-59	-1	-2
144	63	250	-22	-59	-1	0
145	63	249	-22	-59	0	0
146	64	249	-23	-60	-2	-1
147	66	247	-25	-61	-2	-1
148	67	247	-26	-61	-1	0
149	68	246	-27	-62	-2	-3
150	71	247	-28	-65	2	2
151	64	248	-24	-60	3	4
152	63	248	-23	-59	-3	0
153	63	246	-26	-58	-1	0
154	64	248	-24	-59	0	0



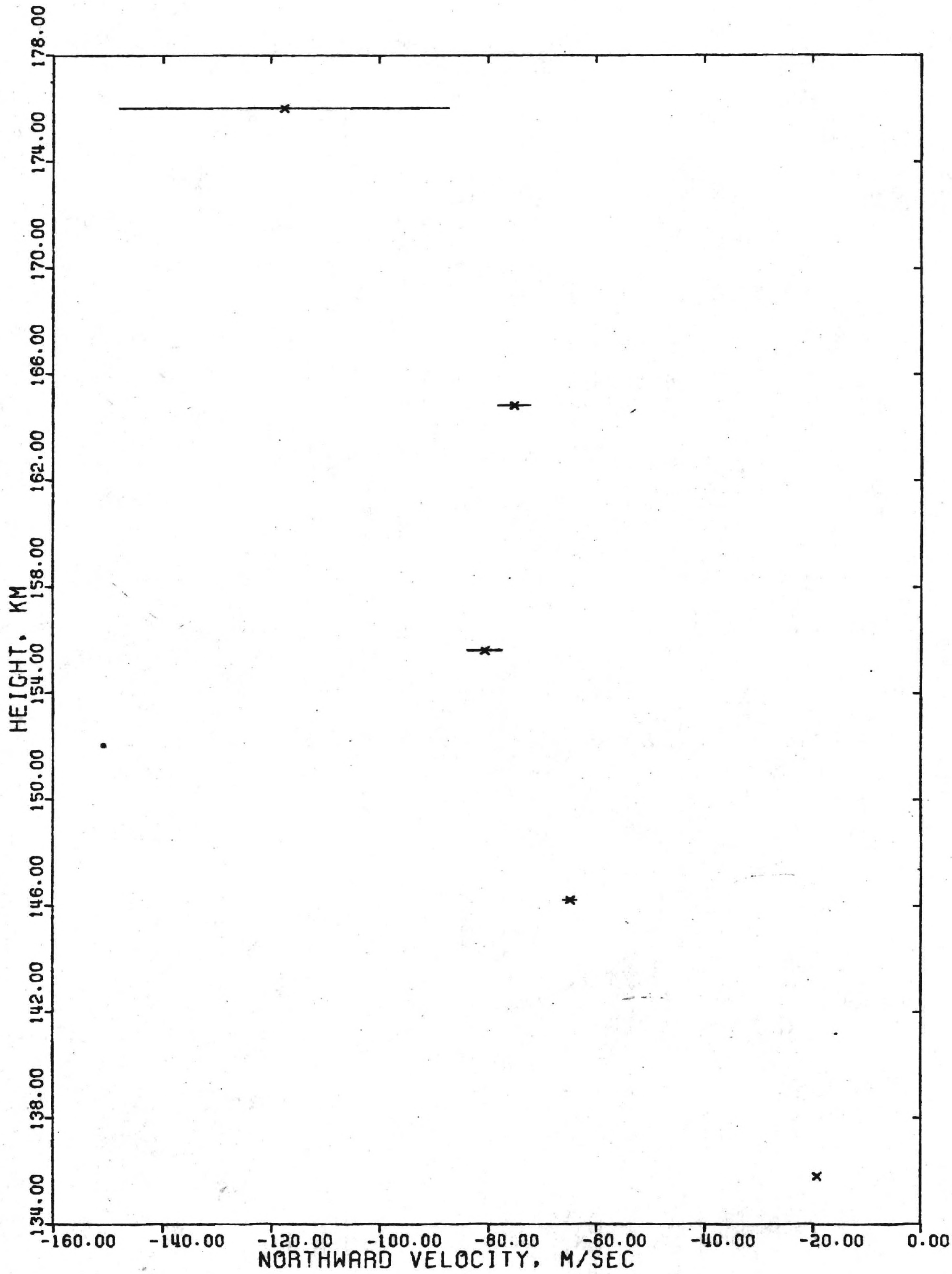
PRE-ALLADIN TRAIL WINDS 1974.5 6/28/74 2110 EDT



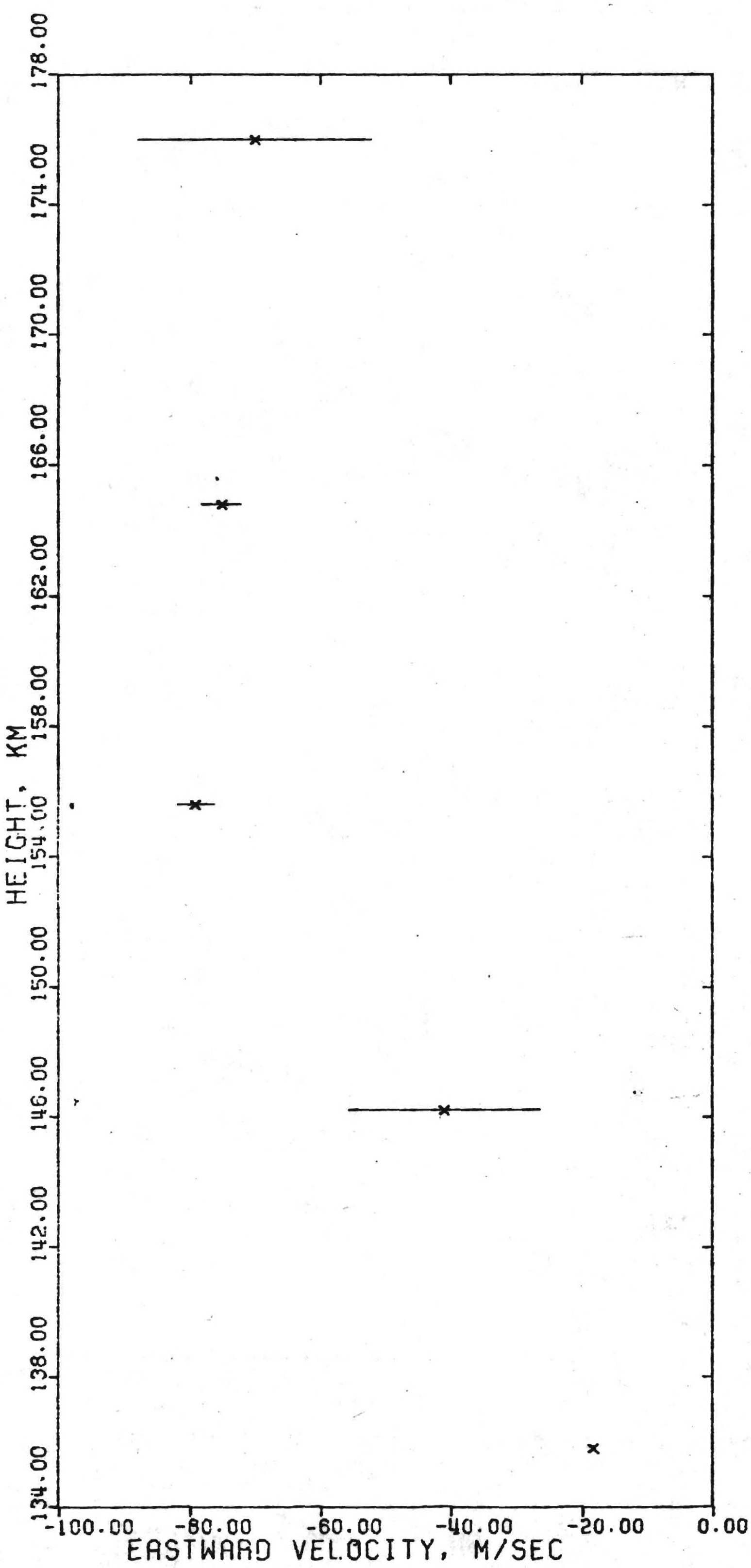
PRE-ALLADIN TRAIL WINDS 1974.5 6/28/74 2110 EDT

CODE NAME.. E1TY LAUNCH DATE.. 6/29/74 TIME.. 2106 EDT

HEIGHT (KM)	SPEED (M/S)	HEADING (DEG)	N-S WIND (M/S)	E-W WIND (M/S)	N-S SHEAR (M/S/KM)	E-W SHEAR (M/S/KM)
******	*****	*******	********	********	*********	*********
135.8	30	224	-19	-18	-5	-1
146.2	78	212	-65	-41	-3	-4
155.6	114	225	-81	-79	0	-2
164.8	107	225	-75	-75	-1	1
176	138	211	-118	-70	0	1



ETTY POINT WINDS 1974.5 6/29/74 2106 EDT



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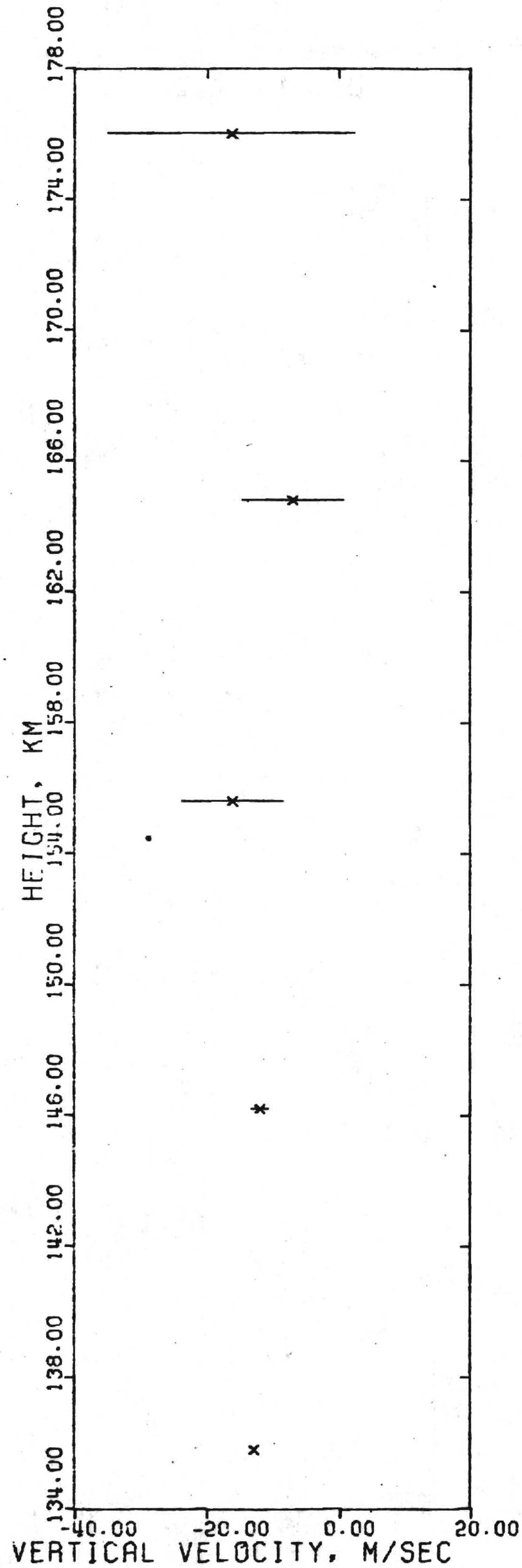
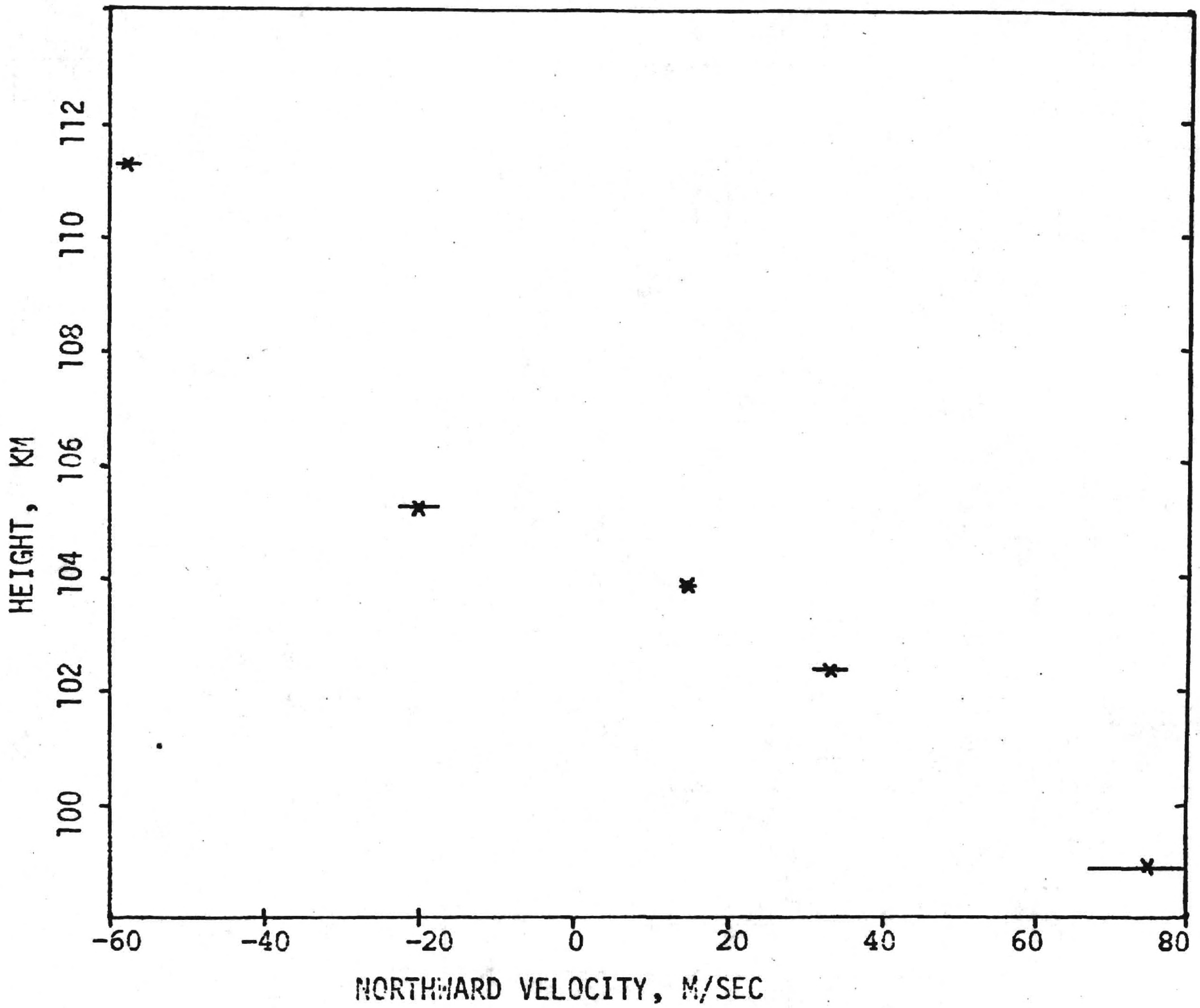


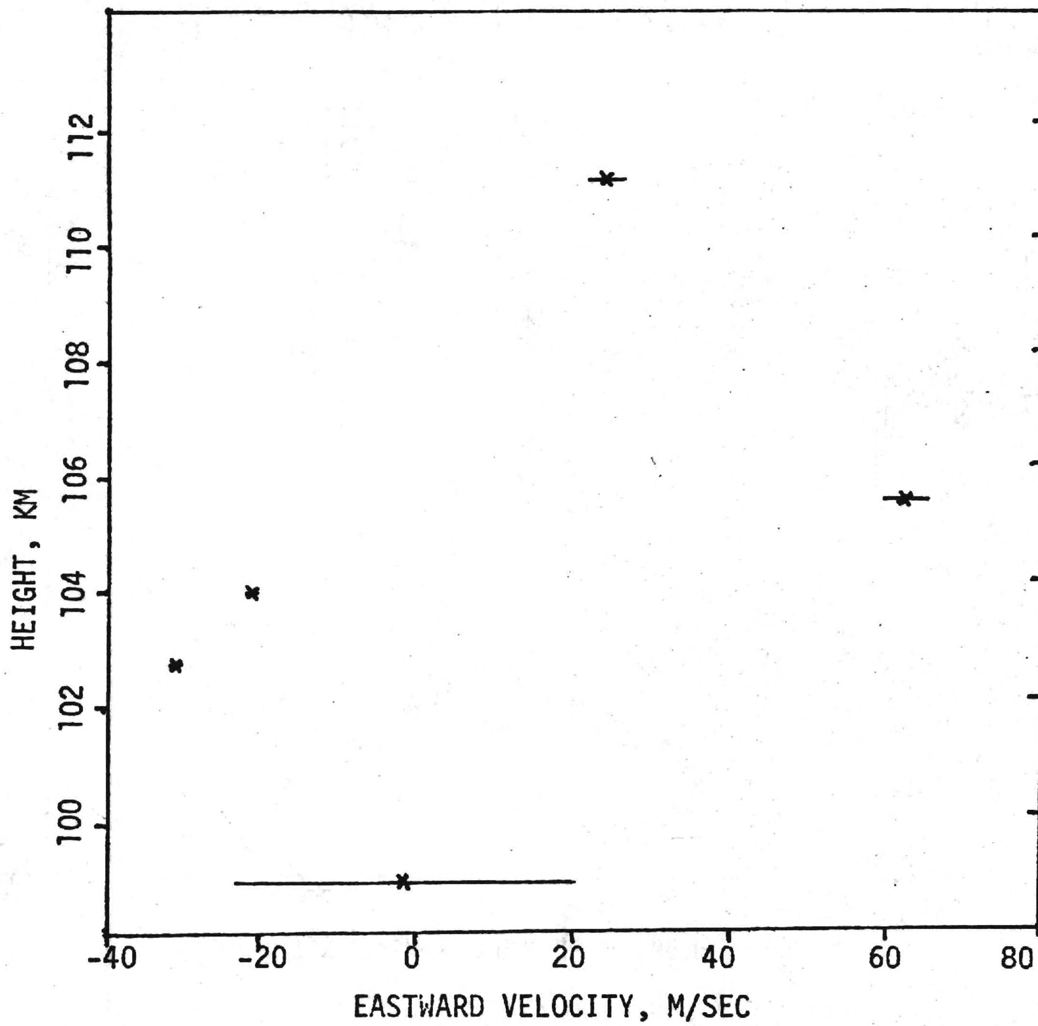
ETTY POINT WINDS 1974.5 6/29/74 2106 EDT

CODE NAME.. JUAN LAUNCH DATE.. 6/30/74 TIME.. 330 EDT

HEIGHT (KM)	SPEED (M/S)	HEADING (DEG)	N-S WIND (M/S)	E-W WIND (M/S)	N-S SHEAR (M/S/KM)	E-W SHEAR (M/S/KM)
******	*****	*******	********	********	*********	*********
99	76	359	76	-1	-12	-14
102.3	56	316	36	-32	-12	-1
103.9	28	310	18	-21	-10	16
108.5	76	105	-20	73	-10	2
111.5	62	157	-57	24	0	0



JOAN POINT WINDS 1974.5 6/30/74 0330 EDT



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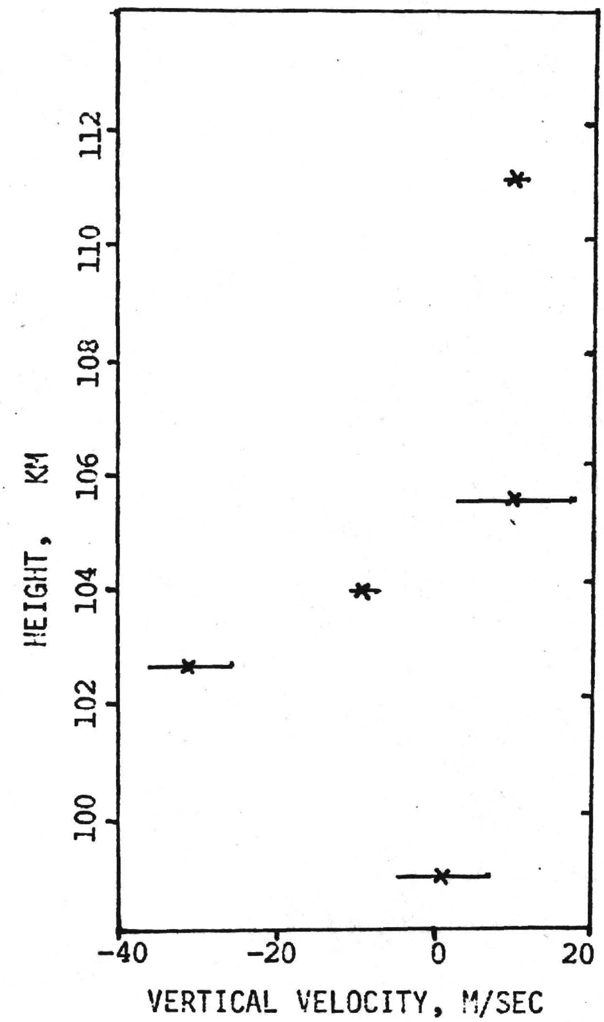

JOAN POINT WINDS 1974.5 6/30/74 0330 EDT

GEORGIA INSTITUTE OF TECHNOLOGY
ATLANTA, GEORGIA 30332

SCHOOL OF
AEROSPACE ENGINEERING

DANIEL GUGGENHEIM SCHOOL
OF AERONAUTICS

~~XXXXXXXXXX~~
404-894-3014

May 16, 1977

Dr. Gene W. Adams,
Atmospheric Research,
NSF Room 312
1800 G Street N.W.,
Washington, D.C. 20550

Subject: Annual Report, and Request for Continuation of
Grant No. ATM75-14414

Dear Gene,

While some problems have been encountered in attempting to operate the Georgia Tech Radio Meteor Wind Facility continuously throughout the second year of the subject three year grant, I am pleased to be able to report that data has been gathered and reduced for more than the two weeks per month originally proposed.

A synopsis of the Atlanta wind results for August, 1974, through December, 1976, is in the process of being printed. This details the variation with height (80 to 100Km) of the prevailing, diurnal and semidiurnal zonal and meridional wind amplitudes over intervals from five days to two weeks throughout this period,

Two Ph.D. candidates are being funded by this grant. One, P.M. Dolas, is currently writing his thesis on the effects of polar stratwarms on lower thermospheric circulation. Some interesting correlations have been observed, and there is evidence of anomalous circulation at meteor altitudes several weeks <u>before</u> the onset of stratwarms. In addition to analysis of meteor data, Dolas was able, using grant funds, to spend a few days at the National Meteorological Center in Washington with Dr. Rod Quiroz, actually participating in the reduction of satellite radiance data to produce maps of stratospheric temperature.

My other Ph.D student, M.L. Salby, has devised an alternate radio meteor wind data analysis procedure, which overcomes some of the objections which have been raised about our routine analysis method, particularly as applied to long term trends in the data. A copy of a paper on this new analysis, as submitted to the Journal of Atmospheric and Terrestrial Physics, is enclosed. Mr. Salby is preparing a thesis on planetary waves in the mesosphere and lower thermosphere.

The joint publication of the results of the first three meteor radar/ incoherent scatter cooperative tidal observation intervals (URSI/IAGA CTOP) mentioned in last years report has turned out not to be as straightforward as I had hoped. However, I have finally obtained a committment from the Journal of Atmospheric and Terrestrial Physics to consider these papers for publication in a single issue in the spring of 1978 (there is an eight month period between submission of final manuscripts to the printer, and eventual publication!). A copy of one of my contributions to this joint effort is enclosed. The continuation of my participation in CTOP has been assured, at least for the next two years, by a separate grant from NSF.

In June of '76 I attended the International Symposium on Solar-Terrestrial Physics in Boulder, principally to participate in the preliminary organization of the joint IAGA/IAMAP Assembly in Seattle in August, 1977. As convenor of the joint Symposium on Electric Currents and Atmospheric Motion in the Lower Thermosphere, I am pleased to be able to report that many international participants will be presenting papers on work which has been coordinated through CTOP.

Immediately after the Boulder meeting, a week was spent at the Middle Atmosphere Program (MAP) planning meeting at the University of Illinois. As conceived, MAP is an attempt to coordinate research on the stratosphere,and mesosphere and lower thermosphere, and to provide some of the "visibility" characteristic of GARP and the IMS.

By personally absorbing some of the costs of travel to and from the fieldsite, I was able to free some grant travel funds which were approved by NSF for travel to the Third European Geophysical Society Meeting in Amsterdam in September '76. In addition to presenting an invited paper (copy enclosed), a visit was made to the Appleton Laboratory in England, and discussions were held in Amsterdam with members of the European E-layer drift network, and some of the CTOP participants.

A further consolidation of cooperation with the meteor wind group at the University of Adelaide was undertaken in October, when I spent two weeks with them under the U.S./Australia Cooperative Science Program (another additional NSF grant). This proved to be a most valuable visit, since only by being with the group during an actual data processing run could a real appreciation for subtle (but significant) differences in interpretation be revealed. While we had hoped to be able to prepare a joint publication of our simultaneously recorded results for the year 1975 early this year, lack of funds (at both ends) hampered this work. However, with the already mentioned NSF grant for cooperative studies coming through in March last, this work is being resumed.

I can see no reason why the progress made over the past two years should not continue during the third year of this grant. The effort to maintain a continuous operating schedule for the Georgia Tech Radio Meteor Wind Facility will continue. Formal publication of the results of the meteor wind/stratwarm correlations, and of the planetary wave investigation, should be forthcoming this year.

I am enclosing a copy of the proposed budget of ATM75-14414 for the year June 1, 1977 - May 31, 1978. The total budget remains unchanged from my original proposal. Minor changes in categories have been made due to changes in approved Retirement Benefits and Indirect Costs.

At this time, it is estimated that there will be no remaining funds at the end of the period for which NSF is currently providing support.

Yours sincerely,

Dr. R.G. Roper, Professor
School of Aerospace Engineering
Principal Investigator

ENDORSEMENT:

Edward E. Renfro, Director
Office of Contract Administration

NSF Grant No. ATM75-14414

"Measurement of Radio Meteor Winds Over Atlanta (34°N, 84°W)"

Year Beginning June 1, 1977

(Third Year)

Budget Category		NSF Funded Man Months Calendar	Proposed NSF (per annum)
A.	SALARIES AND WAGES		
	1. Principal Investigator R.G. Roper, 1/3 time (27% NSF)	3.2	$ 8,820
	2. Other Personnel (non faculty) Graduate Students 2 at 1/3 time	8	$ 8,200
			$17,020
B.	RETIREMENT BENEFITS (9.1% of applicable S & W)		$ 803
	Total S & W and Retirement (A+B)		$17,823
C.	EXPENDABLE SUPPLIES AND EQUIPMENT		$ 803
D.	OTHER COSTS		
	1. Computer CDC CYBER 74, Grantee Owned 2 hours @ $400/hour		$ 800
	2. Travel to and from fieldsite		$ 400
E.	TOTAL DIRECT COSTS (A through D)		$19,826
F.	INDIRECT COSTS on campus 68% of direct S & W		$11,574
	Total Cost (E+F)		$31,400
	TOTAL GRANT (3 years)		$90,600

METEOR WINDS OVER ATLANTA (34° N, 84° W)

August 1974 - February 1976

by

R. G. Roper

School of Aerospace Engineering
Georgia Institute of Technology
Atlanta, GA 30332

Presented at the Third European Geophysical Society Meeting, Amsterdam, September 7-10, 1976.

This research has been supported by the Atmospheric Sciences Section of the National Science Foundation under Grants No. GA26626 and ATM75-14414. Data analysis and interpretation have been supported by the National Aeronautics and Space Administration under Grant No. NGL-11-002-004.

ABSTRACT

An all sky, continuous wave radio meteor wind facility has been operated in Atlanta by the Georgia Institute of Technology under National Science Foundation sponsorship. A double sideband suppressed carrier CW transmitter, operates on 32.5 MHz ± 360 Hz, with an RMS output of 2 KW, on the Georgia Tech campus; the receiving site is at Technology Park/Atlanta, 27 kilometers northeast of the campus. Height/time profiles of mean wind circulation, a two day period "planetary wave", and tides between 80 and 100 kilometers, measured from August 1974 to February 1976 are presented.

INTRODUCTION

The Georgia Tech Radio Meteor Wind Facility which has been in continuous operation since August 9, 1974, is described in detail in Roper (1975). Individual meteor wind dopplers are measured to an accuracy of 3 m/sec, and reflection center heights to ± 2 km. This resolution is ample for the determination of the prevailing and tidal wind observations presented here. Winds are determined by matching the measured line of sight drifts to a model, using the analysis of Groves (1959). Details of the technique are given in Roper (1975).

RESULTS

The results of continuous measurements made from August 9, 1974 through February 1976, less six weeks in April/May, appear in Figures 1 through 4. Only a preliminary assessment of the significance of these results, with particular emphasis on the stratwarm period of January 1 through 17, 1975, is presented here. A more detailed evaluation will eventually be published elsewhere.

In analyzing the raw data, mean values of the prevailing wind, 48, 24, and 12 hour components were extracted over 5 to 20 day intervals, the longer intervals being analyzed when useable echo rates were down. The two day period was extracted simply because it has been noticed on odd occasions at other meteor wind stations, particularly in January data, and was considered as a possible indicator of "planetary wave" penetration into the meteor region from below.

The zonal component of the prevailing wind (the "constant" term in the Fourier series best fitting the data over each interval analyzed) for the nineteen months August 74 - February 76 is shown in Figure 1. The predominantly easterly flow (wind vector directed toward the west) August 74 through January 75 is unexpected. Barnes (1973), for somewhat higher northern latitudes, reports summer and winter westerlies, with equinoctial easterlies, while Elford (1974), for Adelaide, Australia (35° S, 139° E), reports predominant zonal westerlies, maximizing in summer and winter. There is some intriguing structure in the flow - an easing of the easterly flow, with a weak reversal, in late December 74, a return to easterlies in January 75, and then a rapid switch to westerlies in February 75. It is tempting to associate this sequence of changes in December through February with the polar stratwarm of December 15 through February 15 report by Quiroz et al (1975), and regarded as a major warming January 1 through 17.

In January 76, and again in February 76, there are weak reversals of the more usual winter westerlies associated with a "minor" and an "early" warming respectively.

The meridional flow is characterized by generally lower wind speeds, and an indication of a change from northerly flow in summer to southerly flow in winter (in keeping with a warm winter pole at meteor altitudes) with some structure in December-January.

Figure 2 shows zonal and meridional height time profiles of the amplitude of the 48 hour component. Greatest amplitudes, associated with maximum rates of change of amplitude with both height and time, occur in late December 74 - early January 75, and in late February 76. A large amplitude long lived wave is present in the zonal flow in August - September 75.

The diurnal (24 hour) component amplitudes appear irregular, showing considerable structure in both zonal and meridional components in December 74-January 75, and January - February 76.

The semidiurnal (12 hour) component amplitude variations are even more complex. However there is a minimum in both zonal and meridional amplitudes in late December 74, early January 75. This may not be significant (at least in association with the major stratwarm), since the behavior is similar in December 75 - January 76.

CONCLUSIONS

This very preliminary assessment of nineteen months of radio meteor winds measured over Atlanta (34° N, 84° W) demonstrates that continuous recording of radio meteor wind data reveals week by week variations in prevailing, possible planetary wave, diurnal and semidiurnal components which may be able to be directly related to the meteorology of the atmosphere below. In particular, this set of data shows intriguing structure in wind patterns measured over the period of the stratwarm of January 1 - 17, 1975.

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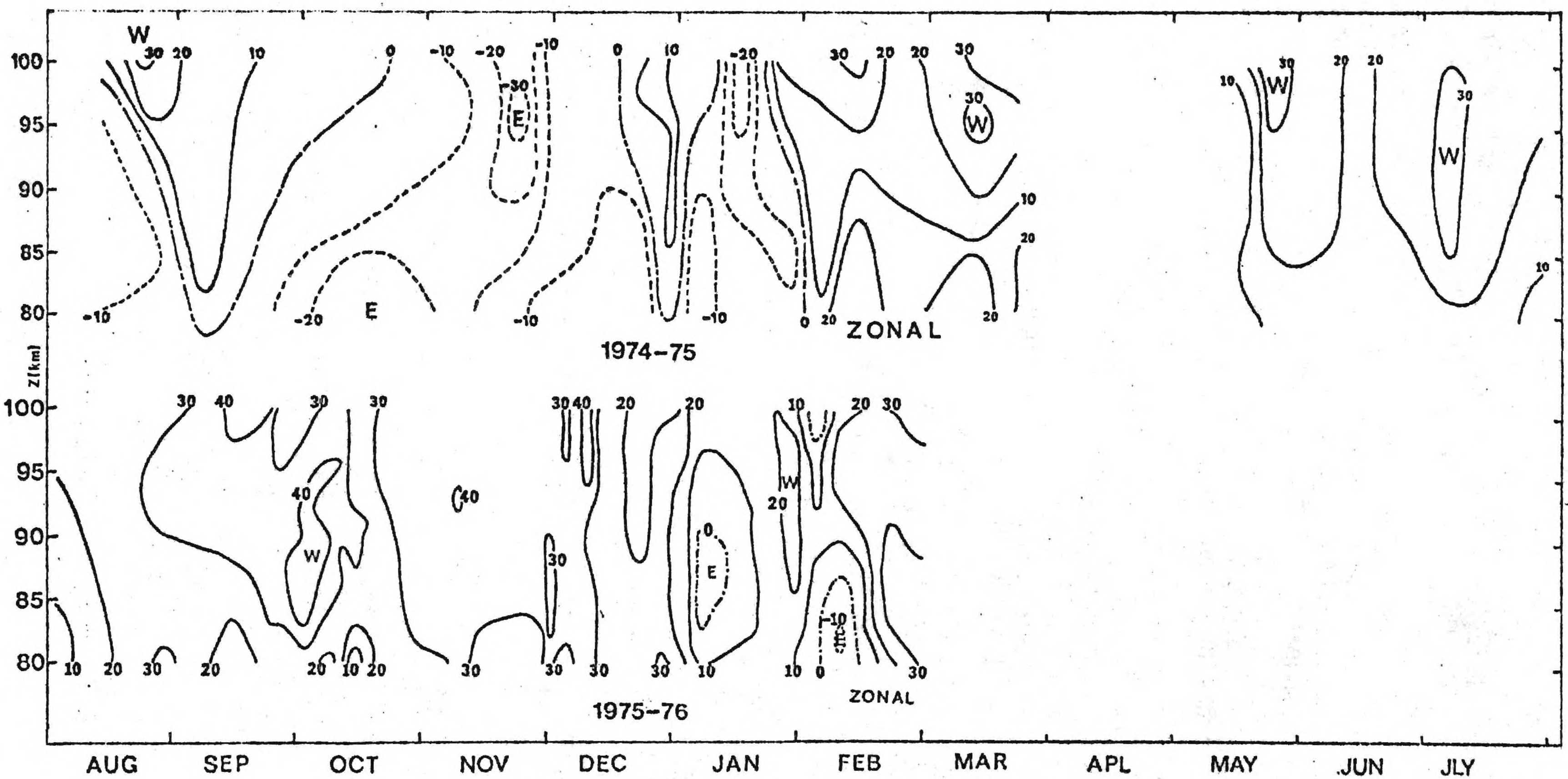
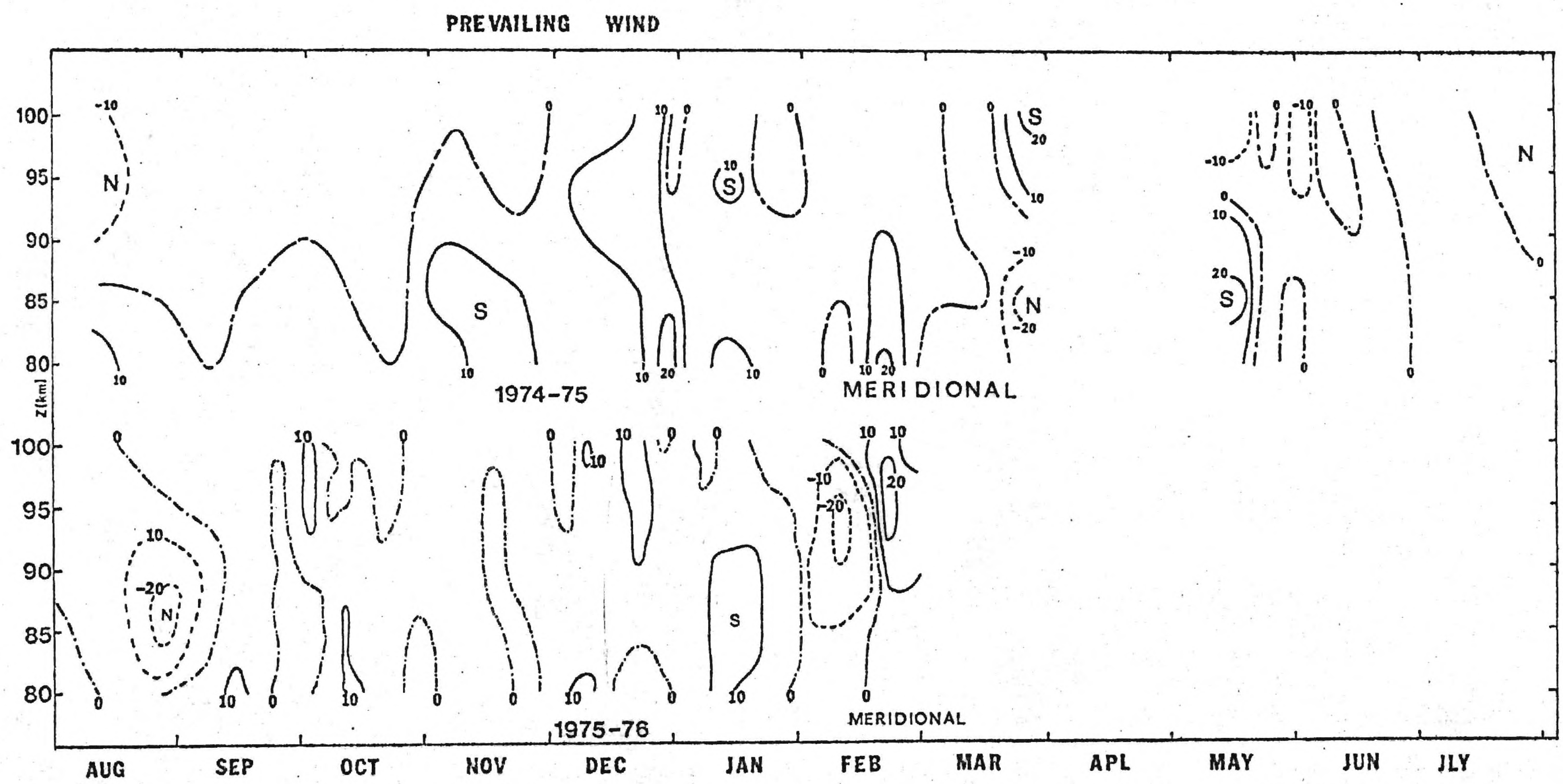
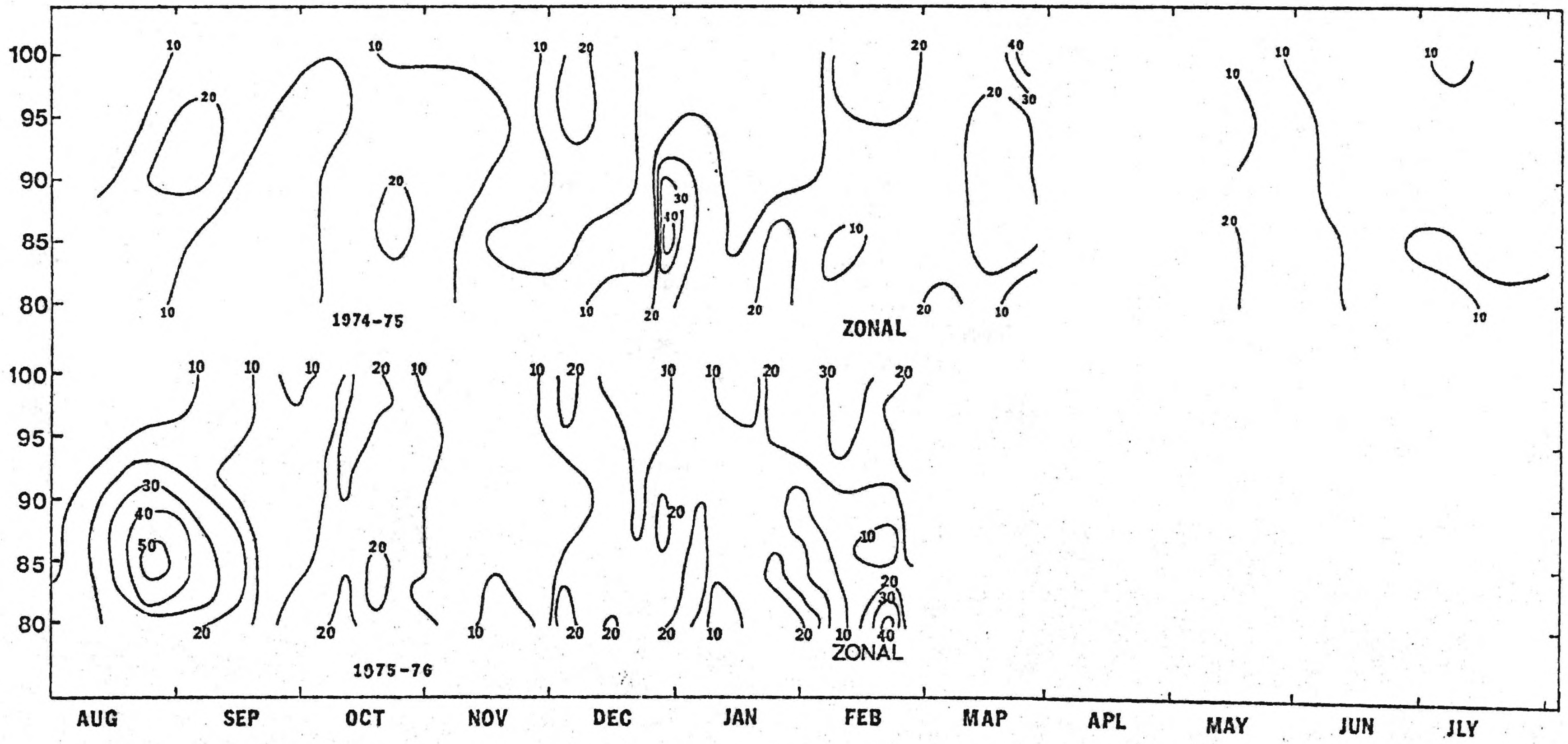
Roper, R. G., "The measurement of meteor winds over Atlanta (34° N, 84° W)", Radio Sci., 10, 363-369, 1975.

PREVAILING WIND

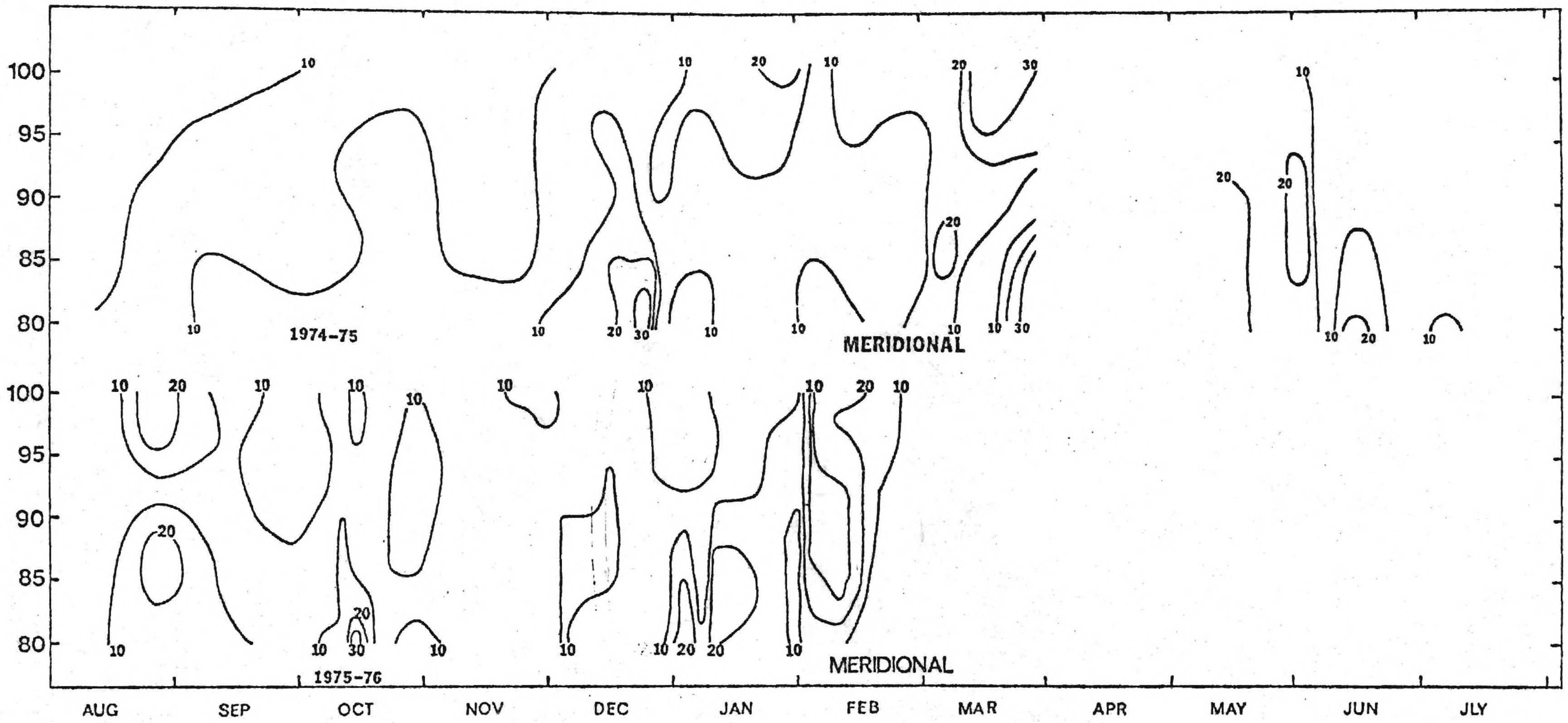



PREVAILING WIND
1974-75
MERIDIONAL
1975-76
MERIDIONAL
z(km)
100
95
90
85
80
AUG
SEP
OCT
NOV
DEC
JAN
FEB
MAR
APL
MAY
JUN
JLY

48 HOUR COMPONENT



48 HOUR COMPONENT



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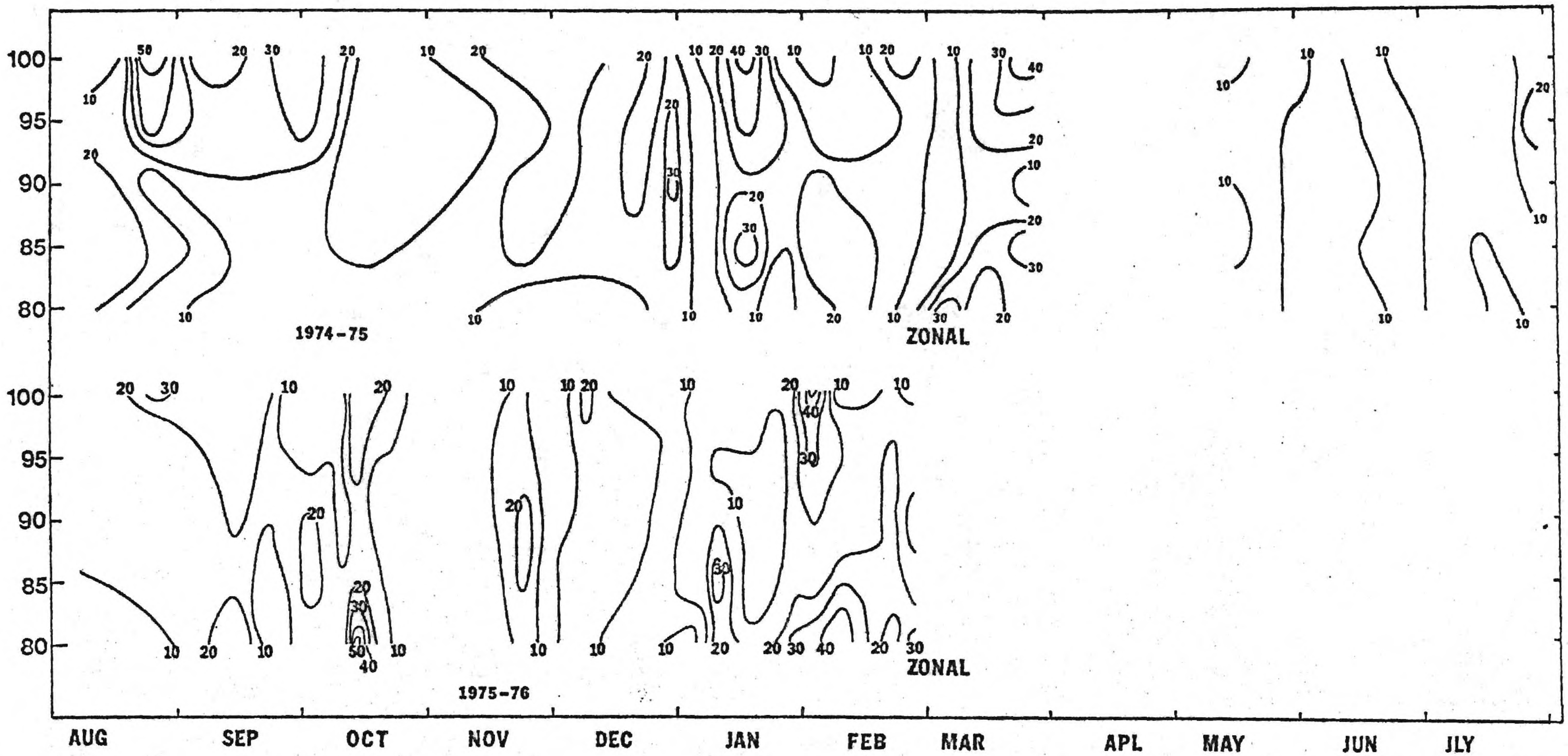

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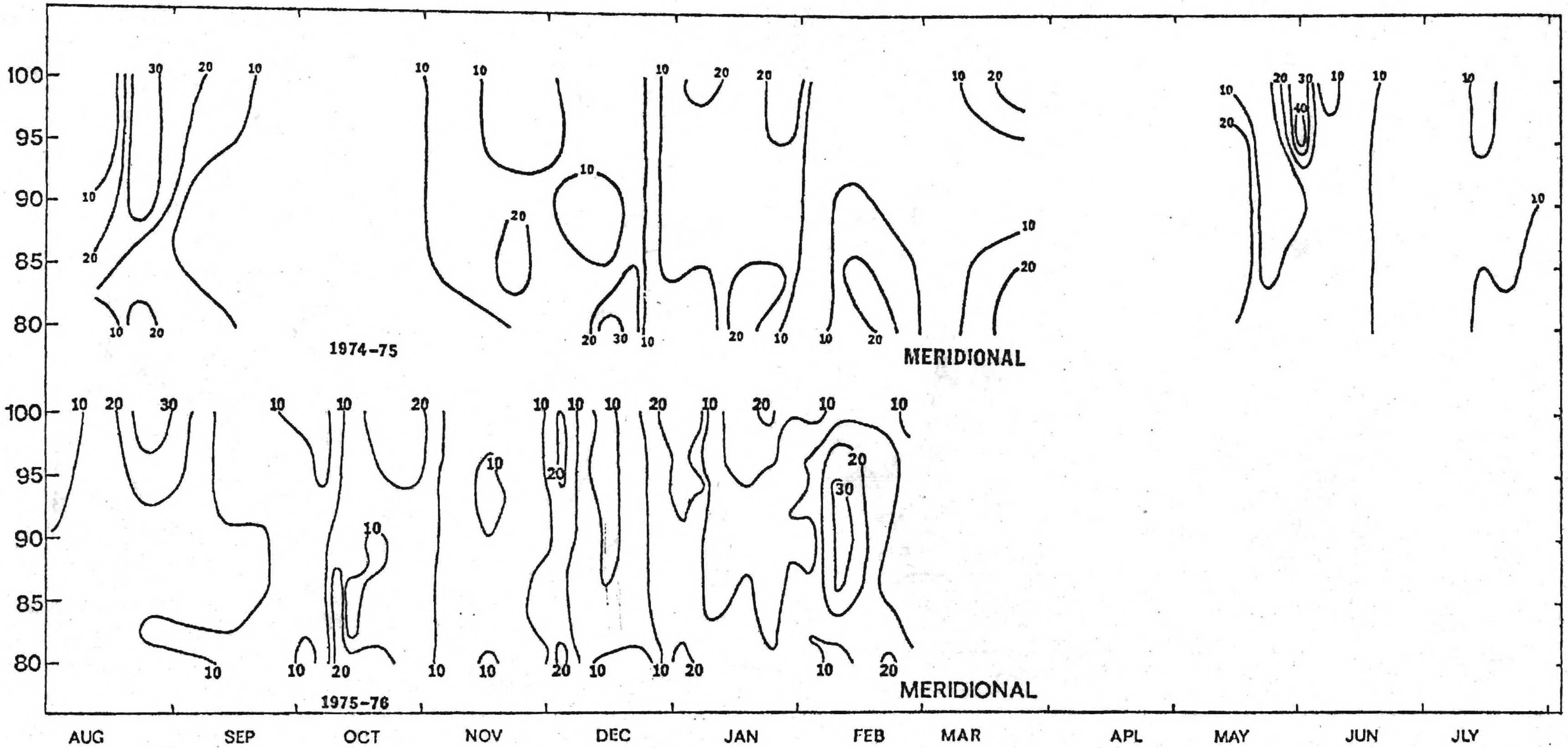

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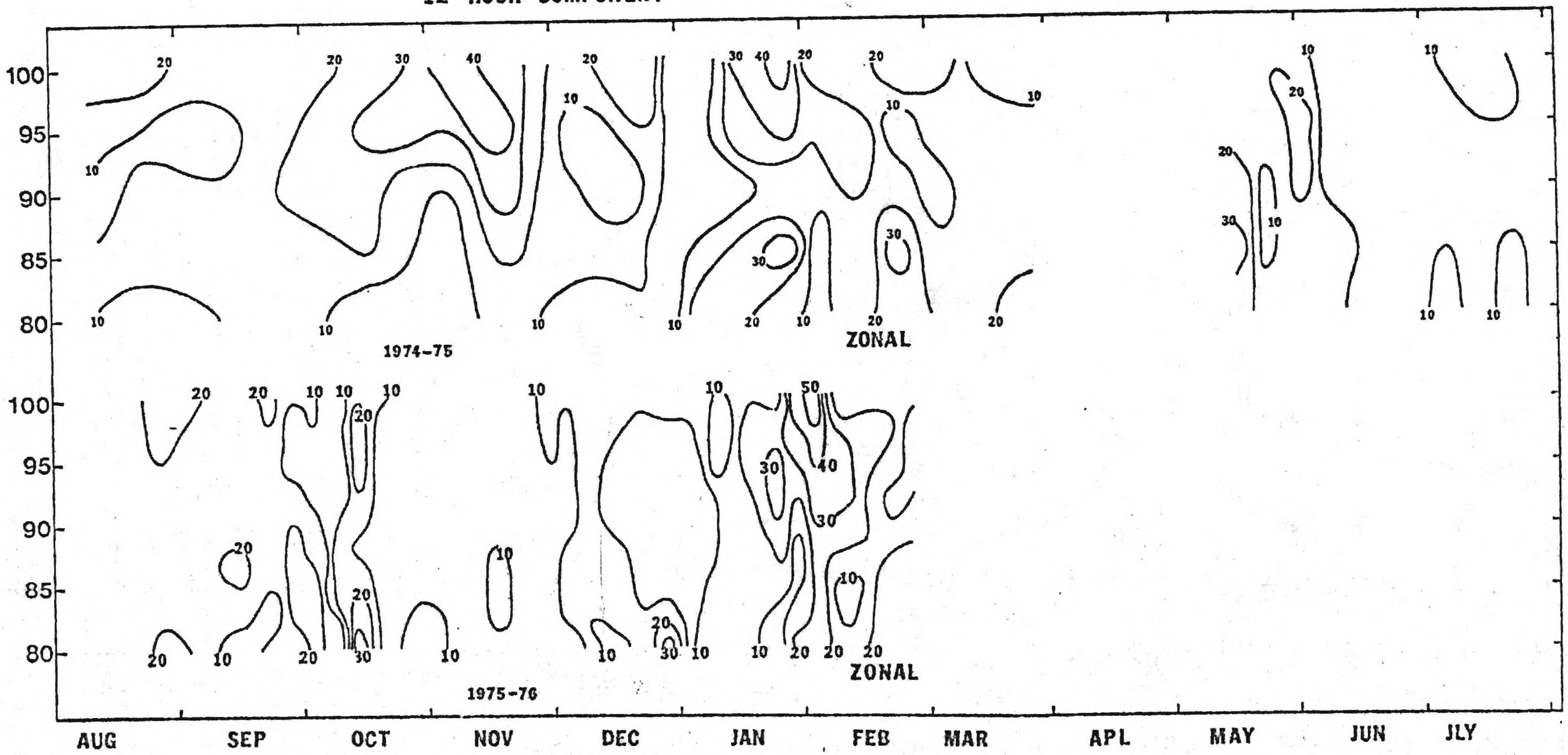

Winds from the Atlanta (34°N, 84°W) Radio Meteor Facility

R. G. Roper

School of Aerospace Engineering
Georgia Institute of Technology
Atlanta, GA 30332 U.S.A.

Introduction

The Georgia Tech Radio Meteor Wind Facility has been in routine operation since August 1974. The facility was designed as a wind measuring system to meet the following criteria:

1. Continuous operation, twentyfour hours a day, seven days a week, with the potential for recording 1000 useable echoes per day;
2. An "all sky" system, with both range and echo arrival angle measured, to give echo heights to $\pm$ 2 km;
3. Continuous wave, with groundwave/skywave beat specifying trail drift doppler; drift measured to $\pm$ 3 m sec^{-1};
4. Minimum bandwidth ($\pm$ 50 Hertz) commensurate with doppler spectrum, ensuring the best possible signal to noise ratio;
5. Data recorded digitally on magnetic tape.

The first three criteria were satisfied by drawing on systems previously described by Weiss and Elford (1963) and Spizzichino (1972). Echo arrival angle is measured with a five antenna interferometer. By using a double sideband suppressed carrier transmitter on 32.5 MHz $\pm$ 360 Hz, range can be measured with the desired accuracy by comparison of the phases of the beats arising from the skywave/groundwave interaction at each of the sideband frequences. The forth criterion has been met by heterodyning the received sidebands to frequencies of 1120 Hz and 1840 Hz, and using passive filters with 100 Hz bandpasses to select the individual sidebands for subsequent processing. Doppler frequency and relative phases are determined by clocking zero crossings - these clock counts, together with digital time, are recorded, after each echo, on magnetic tape in a format compatible with the on campus CDC CYBER 74, which is used for matching the data against a model (Groves, 1959) to produce height profiles of the prevailing, diurnal and semidiurnal winds. The facility has been described by Roper (1975a), and a detailed systems manual is available (Roper, 1975b).

Data rates have not been as high as hoped for - aircraft interference is a major problem. Thus all winds measured are averages over from 5 days to 2 weeks.

Results

Although the Atlanta system operates almost continuously, only three sets of results are presented here, for the cooperative periods August 9-14, 1974, October 15-24, 1975 (c.f. October 13-17), and for January 18-31, 1976, which spans the cooperative period January 19-23, 1976.

Tables 1, 2, and 3 summarize the results of the simultaneous fitting of cubic variations with height to the zonal and meridional components of the prevailing wind and diurnal and semidiurnal oscillations for each of the data sets. The vertical winds were assumed constant with height and periodic in time; for all data sets, the measured vertical winds were less than 10% of the horizontal wind and were not statistically different from zero. Velocities are in m sec^{-1}; phases are the hours of maximum amplitude, local mean solar time (Coordinated Universal Time less 5 hrs, 37 min); a positive zonal wind is a wind vector directed toward the east, that is, a westerly; and a positive meridional wind is a southerly. Errors are one standard deviation, and represent the least-squares error between the measured data and the model best fitting the data. Thus the error contains not only the errors inherent in the measurement of the line of sight velocity, but also naturally occurring wind fluctuations. The latter are by far the most significant.

The detailed discussion of these and other results will appear elsewhere, but some comment on the tables presented is pertinent. The tabled values are the means of each component over the interval of measurement. Groves' method of analysis enables the calculation of a measure of the fit achieved by the model to each of the components of the measured wind field - this is the "error" associated with each component. The column titled "Mean" in the tables is the prevailing wind, i.e., the amplitude of the constant term in the truncated Fourier series best fitting the total wind field at any given altitude over the analyzed time interval. No attempt has been made in the analysis to extract periodicities greater than diurnal. Synoptic scale disturbances do exist in the meteor region, and will significantly contaminate the prevailing wind fields as presented here. Long term variations are being investigated, and will be reported elsewhere (Salby and Roper, 1977).

In the August '74 period the prevailing zonal wind was easterly below 96 kilometers, with westerlies above. This constrasts with the strong westerlies over the whole 80 to 100 kilometer height range in October '75, and the somewhat weaker but equally persistent westerlies in January '76. The meridional wind was northerly in August '74, and above 90 kilometers in October '75, with southerlies below 90 kilometers in October '75, and below 96 kilometers in January '76.

The diurnal oscillation measured for all three of these intervals is difficult to identify as a "tide". Technically, since the atmospheric tides are global phenomena, measurement on a global scale is required for identification. However, if measurements at a single site produce a diurnally or semidiurnally varying wind with a northward component leading the eastward component in phase by a quarter cycle, with the hour of maximum in each of these directions, and the vertical wavelength (unless evanescent) corresponding to a theoretical tidal model, the measured oscillation is usually considered to be identified as tidal. In looking at the diurnal component as measured in August '74, one finds the northward component leading the eastward component by 7 hours at 80 km, but in approximately antiphase over the rest of the height range. In October '75, the northward component leads the eastward component by 6 hours at 100 km, and by from 4 to 7 hours over the height range measured. In January '76, the northward leads the eastward by 9 hours, with amplitudes too small to make effective comparisons at other heights.

Even with the semidiurnal oscillation, which is usually a more regular feature of the midlatitude meteor wind regime, no positive identification is possible for any of the intervals presented here. In August '74, amplitudes are significant above 90 km, with the eastward component leading the northward component by a few hours, although, when the error in phase determination is considered, these components are not significantly different from being in antiphase. In October '75, low zonal amplitudes make phase comparisons meaningless, and in January '76, the semidiurnal components are almost antiphase below 92 km, and almost in phase above.

When those results obtained over Atlanta since 1974 which are not presented here are also taken into consideration, the above are not atypical. In particular, results obtained at latitude 34° N do seem to be significantly different in many respects from those obtained at higher northern latitudes.

Conclusions

A highly reliable, relatively inexpensive CW meteor radar, capable of measuring the variation of wind speed with altitude, with individual drifts to $\pm$ 3 m sec^{-1}, $\pm$ 2 km in height, is in operation in Atlanta (34°N, 84°W). This station is being operated continuously, providing data on the height/time variations of prevailing and tidal winds over the height range 80 to 100 km. Particular emphasis is now being placed on the investigations of planetary wave amplitudes and frequencies, and through GRMWSP, the Global Radio Meteor Wind Studies Project of the International Association of Geomagnetism and Aeronomy, on the synoptic meteorology of this region.

Acknowledgments

The Georgia Tech Radio Meteor Wind Facility was initially funded by the Georgia Institute of Technology. Since 1971, it has been supported by the Atmospheric Sciences Section of the National Science Foundation under grants GA26626 and DES75-14414. Data analysis and interpretation is supported by the National Aeronautics and Space Administration under grant NGL 11-002-004.

References

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TABLE 1

Zonal and Meridional Components of the Wind, Amplitude, and Phase (August 9, 1974, to August 14, 1974).

		24.0 Hour Component					12.0 Hour Component			
Height	Mean	Error	Amp	Error	Phase	Error	Amp	Error	Phase	Error
East-West										
100	16.	9.	5.	13.6	22.5	10.	27.	13.2	11.8	1.
96	-3.	8.	10.	11.6	15.9	4.	29.	11.6	11.2	1.
92	-12.	6.	15.	9.6	16.1	2.	18.	9.5	11.2	1.
88	-14.	7.	17.	10.1	16.4	2.	5.	9.5	1.4	4.
84	-10.	8.	19.	11.5	16.0	2.	11.	10.6	3.8	2.
80	-1.	13.	28.	17.0	14.6	3.	5.	17.3	3.2	7.
North-South										
100	-10.	7.	3.	9.6	9.7	15.	21.	10.7	4.6	1.
96	-11.	7.	1.	9.2	20.7	38.	19.	10.0	5.1	1.
92	-10.	5.	5.	7.6	2.1	6.	18.	7.6	4.9	1.
88	-7.	6.	11.	8.1	3.6	3.	14.	7.8	4.5	1.
84	-4.	7.	15.	9.5	5.0	2.	6.	9.4	3.0	3.
80	-3.	10.	16.	15.0	7.5	3.	18.	13.7	11.0	2.

TABLE 2

Zonal and Meridional Components of the Wind, Amplitude, and Phase (October 15, 1975 to October 24, 1975).

		24.0 Hour Component					12.0 Hour Component			
Height	Mean	Error	Amp	Error	Phase	Error	Amp	Error	Phase	Error
East-West										
100	30.	9.	21.	12.0	16.1	2.	11.	11.0	10.8	2.
96	31.	8.	13.	10.5	16.0	3.	5.	10.2	10.2	4.
92	29.	7.	6.	11.4	13.5	5.	0.	8.8	10.1	39.
88	25.	8.	8.	12.8	10.	5.	3.	9.7	3.0	9.
84	23.	9.	11.	13.8	10.2	4.	3.	11.8	2.1	7.
80	24.	11.	13.	17.6	13.2	4.	5.	18.1	11.1	6.
North-South										
100	-9.	7.	24.	10.1	9.9	1.	9.	8.4	4.8	2.
96	-6.	6.	20.	10.2	10.4	2.	6.	7.7	4.1	3.
92	0.	6.	11.	7.7	9.4	3.	7.	7.6	5.4	2.
88	7.	6.	9.	7.4	5.8	5.	13.	9.7	6.0	1.
84	10.	7.	14.	7.9	5.7	3.	21.	9.7	5.8	1.
80	5.	9.	24.	11.7	8.5	2.	29.	12.3	5.1	1.

TABLE 3

Zonal and Meridional Components of the Wind, Amplitude, and Phase (January 18, 1976 to January 31, 1976).

			24.0 Hour Component				12.0 Hour Component			
Height	Mean	Error	Amp	Error	Phase	Error	Amp	Error	Phase	Error
East-West										
100	20.	12.	20.	19.2	24.0	3.	10.	16.4	6.9	3.
96	19.	10.	7.	11.8	6.6	10.	29.	14.0	6.4	1.
92	17.	8.	9.	11.3	10.0	5.	33.	11.0	6.3	1.
88	15.	8.	8.	12.8	12.6	5.	26.	11.2	6.2	1.
84	16.	9.	11.	15.9	13.8	4.	12.	12.9	6.2	2.
80	20.	13.	20.	18.9	12.1	3.	6.	16.8	10.5	5.
North-South										
100	-10.	10.	22.	16.4	14.8	2.	28.	14.4	7.5	1.
96	0.	9.	11.	13.8	14.0	4.	13.	12.6	7.1	2.
92	4.	7.	5.	10.3	10.9	8.	6.	8.8	11.0	3.
88	5.	7.	6.	8.5	7.2	6.	19.	8.6	11.7	1.
84	4.	7.	8.	9.1	7.4	6.	20.	9.5	11.9	1.
80	3.	10.	11.	11.9	9.8	5.	6.	14.0	2.8	4.

RADIO METEOR WIND DECOMPOSITION USING FINITE ELEMENT APPROXIMATION

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Abstract

A method for decomposing radio meteor wind data into representations of the instantaneous velocity component functions is introduced. The technique employs finite element least squares approximation, and is spectrally unbiased and limited in resolution essentially only by the data. The decomposition is demonstrated on both known test functions and actual meteor wind data.

Radio Meteor Wind Decomposition Using
Finite Element Approximation

1. Introduction and Background Material

The radio-meteor technique for measuring upper atmospheric winds has been in use internationally for many years. Briefly, radio waves are transmitted from one site, reflected by an ionized meteor trail (which is assumed to drift with the ambient velocity) and finally received at another site. Because of the drift velocity of the trail, the frequency of the reflected waves is doppler shifted. The direction of arrival and the range of the reflected wave or "echo" gives the location of the reflecting point, and the doppler shift yields a velocity component at that point. For a more detailed study see McAvaney (1970). Unfortunately, the velocity determined by this measured doppler frequency shift is not the true velocity $\vec{V}$, but rather the line of sight velocity $\vec{V}_L$, i.e.: the component of the actual wind velocity along the line of sight between the receiving station and the reflecting point on the trail (Fig. 1).

In general the velocity field is expected to be a vector valued function over an appropriate volume crossed with a time domain:

$$\vec{V} = \vec{V}(x_1, x_2, x_3, t) = V(\vec{x}, t)$$

or equivalently it may be represented by the three component functions over the position $\times$ time domain:

$$v_1 = v_1(\vec{x}, t)$$
$$v_2 = v_2(\vec{x}, t)$$
$$v_3 = v_3(\vec{x}, t)$$

(χ is the cartesian product operation e.g. if A and B are two intervals then the cartesian product A χ B is the rectangle given by $\{(t, z); t\varepsilon A, z\varepsilon B\}$.) Here the standard coordinate convention is used: subscripts 1, 2 and 3 denote EW, NS and vertical directions respectively. A typical measurement volume might be a circular slab of atmosphere centered above the receiving site 400 km in diameter extending from 70 to 120 km, in the vertical (Fig. 1).

It is often assumed that the wind field is independent of the horizontal position in the measurement volume, which implies

$$\vec{V} = \vec{V}(z, t)$$

where we let $z = x_3$. Motivation for this is horizontal scales of interest are expected to be considerably larger than the horizontal dimensions of the volume (A. Spizzichino, 1971). Thus the problem is reduced to determining a vector valued function $\vec{V}$, or equivalently the three component functions v_k, over a two dimensional domain D of height χ time. Typically, the problem might be to determine the vector values over a strip of length T, ranging from 70 to 120 km, i.e. vectors corresponding to all points (t, z) in this strip (Fig. 2).

Any three-dimensional vector may be determined by resolving (measuring) three linearly independent components, i.e.: projecting it along three linearly independent directions. Unfortunately, most meteor wind facilities have only one receiving site and hence measure velocity along only one line of sight. Thus only one of the three required components is measured at any (t, z) in the domain. Moreover, since the incidence of meteors is random in space and time, the points where measurements are taken are randomly distributed across the domain of interest, as are the direction cosines associated with the lines of sight.

The line of sight velocity at any point $(t, z) \epsilon D$ is given by:

$$\vec{V}_L = (\vec{V} \cdot \vec{e}_L)\vec{e}_L \tag{1}$$

where:

$\vec{V}$ is the true velocity

$\vec{V}_L$ is the line of sight component

$\vec{e}_L$ is a unit vector along the line of sight (Fig. 3).

Now:

$$e_{L_j} = \cos \alpha_j = d_j \tag{2}$$

where d_j are the direction cosines associated with the line of sight (Fig. 3). Thus the "signed magnitude" of the line of sight velocity is given by:

$$V_L = \vec{V} \cdot \vec{e}_L = v_k d_k \tag{3}$$

or

$$V_L = d_1 v_1 + d_2 v_2 + d_3 v_3 \tag{3'}$$

We see the measured line of sight velocity $\vec{V}_L(t, z)$ is a linear combination of the three components of the true velocity $\vec{V}(t, z)$, where the coefficients are the "random" direction cosines. This gives but one equation in the three unknowns $v_k(t, z)$: at the pt. (t, z). Still needed are two other linearly independent equations in the velocity components at (t, z). Thus if there are N measurements at points $\{(t_\mu, z_\mu)\}_{\mu=1}^{N}$ there are 3N corresponding unknowns: $\{v_k (t_\mu, z_\mu)\}_{\mu=1}^{N}$, $k = 1, 2, 3$.

Obviously, some assumptions must be introduced to close the problem. One of the earlier techniques, which remains in use (Clark, 1975), partitions the time height domain into several subregions in which $\vec{V}(t, z)$ is assumed constant. This method has obvious drawbacks in consideration of velocity height variations, evolution of the wind field, and spectral resolution. Another alternative is to sample only echoes arriving along a given direction, thereby measuring a given component at different (t, z). This closes the problems mathematically yet fails to give a complete description of the velocity field.

In 1959 G. V. Groves (Groves, 1959) established a technique which solved the problem in a "least squares" sense. The unknown velocity component functions were assumed to be given function of time and height with arbitrary parameters. These parameters were then chosen so as to minimize the error in V_L, as formed by these functions, compared with the actual measurements of V_L. The general technique as used at the University of Adelaide in South Australia and the Georgia Institute of Technology in Atlanta employs a cubic polynomial in height and the first four terms of a Fourier series in time where the fundamental period is chosen to be the length of the interval under study. This is usually chosen as 24 hours. Motivation for this choice of the temporal behavior of the velocity is to provide a harmonic decomposition of the wind field. Spectral analysis is a primary tool for analyzing upper atmospheric data. Thus after performing the Groves analysis, at any fixed height z there will exist three time sequences for the three velocity components v_k, each of which will have exactly three spectral constituents. Similarly at any fixed time t, there will exist three velocity height profiles, each of which may vary as at most, a cubic polynomial. Also in order to have a large ensemble of data points in the period of interest, data from several adjacent periods is superimposed - as if it occurred in the same period.

There are several points that must be questioned concerning the previous technique. Of primary importance is the connection of spectral analysis to the velocity components v_k. If one assumes a discrete set of harmonic components for the temporal behavior of $v_k(t, z)$, one expresses a priori knowledge of not only the number of such components, but more importantly the frequencies associated with them (see Clark, 1975). That is the data is "preanalyzed" to have a spectrum containing only these frequencies. In general such an omniscient assumption is unwarranted. If a fundamental (largest) period is known to exist in the data, then a harmonic analysis may be performed using a Fourier series with the first harmonic term having period equal to this fundamental. Unfortunately, this is very unlikely in almost all geophysical data, in particular atmospheric data. Probably the best choice for a fundamental period would be one year, but even this would have its limitations due to solar cycle variations, etc. Classical spectral and harmonic analyses require stationarity - in essence the mean and spectral content are independent of time. Again, unlike laboratory situations, this is not the case in most geophysical phenomena. If this is not the case, nonstationarities must be accounted for so as not to distort the spectrum. Assuming $v_k(t, z)$ to behave as a truncated fourier series in t implies the existance and knowledge of a fundamental period. Obviously this is not the case, and the consequences will fall into the temporal behavior and spectral content of the velocity components.

Recall the Groves technique as used in Adelaide and Atlanta employs superposition of data in several adjacent time intervals. This amounts to averaging adjacent time spans. Consider a time sequence of some function f(t) over an interval [o, NT) (Fig. 4). If the function values over adjacent intervals of length T are averaged, then the corresponding Fourier transforms will also be averaged due to linearity of the Fourier transform. Defining the kth function as:

$$f_k(t) = f(t + kT) \quad t \varepsilon [0, T] \; k = 0, 1, 2, \ldots N-1 \qquad (4)$$

and assuming stationarity over intervals of length T, it is easily shown that f_k has the Fourier transform:

$$F_k(\nu) = F(\nu)\, e^{i2\pi\nu kT} \tag{5}$$

where $F(\nu)$ is the Fourier transform of $f(t)$ $t\epsilon[0, T)$ (Bath pp 44).

Averaging these functions we have:

$$\frac{1}{N}\sum_{k=0}^{N-1} f_k(t)$$

with corresponding Fourier transform:

$$\frac{1}{N}\sum_{k=0}^{N-1} F_k(\nu) = F(\nu)\,\frac{1}{N}\sum_{k=0}^{N-1} e^{i2\pi\nu kT} \tag{6}$$

In general the summation involved in the transform will lead to cancellation. That is for N sufficiently large, the value of the Fourier transform of the average will tend to zero for general ν. If however ν is such that

$$2\pi\nu kT = 2\pi n$$

for all k for some integer n

i.e. $$\nu = n/T. \tag{7}$$

then the Fourier transform of the average at these ν will in fact equal that of $f(t)$ $t\epsilon$ $[0, T)$.

Thus the effect of averaging adjacent intervals is to cancel the Fourier transform and hence the power spectrum for all frequencies other than those periodic in T (obviously, if a component is periodic in T/n it is periodic in T). Therefore after sufficient averaging, only those frequency components that are "window periodic" will survive (the sample interval is often referred to as the "time window").

If the velocity functions were stationary, and if this averaging were performed sufficiently, then only the window periodic frequency components would remain. Then a Fourier series might be fitted to the data with fundamental period equal to the length of the time interval. However, stationarity does not exist, and the question of an appropriate fundamental period or sample time remains unanswered. Additionally, the destruction of the spectral content except at the window periodic frequencies is also a questionable point. Indeed, the dominant features of the spectrum may be lost in such a process.

Finally, resolution of the wind field in the vertical is limited to that of a cubic polynomial, which may have at most two critical points.

The Groves technique was unquestionably a major step in the reduction and analysis of meteor wind data. It was certainly superior to the methods used at the time of its introduction. Yet, the previous discussion seems to indicate that a somewhat different approach would be warranted.

2. Development of the Problem

The problem is to determine representations of the unknown velocity component functions over a suitable domain of interest. We take this to be a strip in the t - z plane of length:

$$T = t_F - t_0$$

width $z_F - z_0$ (Fig. 5).

Since it takes three linearly independent measurements at a single point (t, z) to determine the three unknowns $v_k(t,z)$, we attempt to relax the problem and relate observations at nearby points (Fig. 5). We do this by allowing the velocity functions to vary in some continuous manner between the different observation points.

We assume that there are N line of sight observations: $\{V_{L\mu}\}_{\mu=1}^{N}$ at N points: $\{(t_\mu, z_\mu)\}_{\mu=1}^{N}$ in the domain with N corresponding sets of direction cosines: $\{d_{1\mu}\}_{\mu=1}^{N}$, $\{d_{2\mu}\}_{\mu=1}^{N}$, $\{d_{3\mu}\}_{\mu=1}^{N}$. Thus we have N equations:

$$V_{L\mu} = d_{1\mu}\, v_1(t_\mu\, z_\mu) + d_{2\mu}\, v_2(t_\mu\, z_\mu) + d_{3\mu}\, v_3(t_\mu\, z_\mu)$$

$$\mu = 1, 2, \dots N$$

As in the classical Least Squares (LS) Problem, we assume the unknown functions $v_k(t,z)$ to be composed of a linear combination of p_k approximating functions $Z_j^k(t,z)$ $j = 1, 2, \dots p_k$, plus an error term $\varepsilon_k(t,z)$, $k = 1, 2, 3$.
That is

$$v_1(t,z) = \alpha_1\, Z_1^1(t,z) + \alpha_2\, Z_2^1(t,z) + \dots + \alpha_{p_1}\, Z_{p_1}^1(t,z) + \varepsilon_1(t,z)$$

$$v_2(t,z) = \beta_1\, Z_1^2(t,z) + \beta_2\, Z_2^2(t,z) + \dots + \beta_{p_2}\, Z_{p_2}(t,z) + \varepsilon_2(t,z)$$

$$v_3(t,z) = \gamma_1\, Z_1^3(t,z) + \gamma_2\, Z_2^3(t,z) + \dots + \gamma_{p_3}\, Z_{p_3}(t,z) + \varepsilon_3(t,z)$$

or

$$v_1(t,z) = \sum_{j=1}^{p_1} \alpha_j\, Z_j^1(t,z) + \varepsilon_1(t,z)$$

$$v_2(t,z) = \sum_{j=1}^{p_2} \beta_j\, Z_j^2(t,z) + \varepsilon_2(t,z)$$

$$v_3(t,z) = \sum_{j=1}^{p_3} \gamma_j\, Z_j^3(t,z) + \varepsilon_3(t,z)$$

The α_j, β_j, and γ_j are the as yet undetermined coefficients of the approximating functions $Z_j^1(t,z)$, $Z_j^2(t,z)$ and $Z_j^3(t,z)$, where there are p_1, p_2, and p_3 of each respectively.

To simplify matters we will approximate all three of the velocity functions by the same set of estimating functions: $Z_j(t,z)$, i.e.:

$$Z^k_j(t,z) = Z_j(t,z) \qquad j = 1,2,3, \dots p \tag{10}$$

(9') then reduces to:

$$\begin{aligned} v_1(t,z) &= \sum_{j=1}^{p} \alpha_j Z_j(t,z) + \varepsilon_1(t,z) \\ v_2(t,z) &= \sum_{j=1}^{p} \beta_j Z_j(t,z) + \varepsilon_2(t,z) \\ v_3(t,z) &= \sum_{j=1}^{p} \gamma_j Z_j(t,z) + \varepsilon_3(t,z) \end{aligned} \tag{11}$$

In particular, for the N observations at the points $\{t_\mu, z_\mu\}_{\mu=1}^{N}$

$$\begin{aligned} v_1(t_\mu,z_\mu) &= \sum_{j=1}^{p} \alpha_j Z_j(t_\mu,z_\mu) + \varepsilon_1(t_\mu,z_\mu) \quad \mu = 1,2, \dots N \\ v_2(t_\mu,z_\mu) &= \sum_{j=1}^{p} \beta_j Z_j(t_\mu,z_\mu) + \varepsilon_2(t_\mu,z_\mu) \quad \mu = 1,2, \dots N \\ v_3(t_\mu,z_\mu) &= \sum_{j=1}^{p} \gamma_j Z_j(t_\mu,z_\mu) + \varepsilon_3(t_\mu,z_\mu) \quad \mu = 1,2, \dots N \end{aligned} \tag{12}$$

or

$$\begin{aligned} \vec{v}_1 &= \mathcal{Z}\vec{\alpha} + \vec{\varepsilon}_1 \\ \vec{v}_2 &= \mathcal{Z}\vec{\beta} + \vec{\varepsilon}_2 \\ \vec{v}_3 &= \mathcal{Z}\vec{\gamma} + \vec{\varepsilon}_3 \end{aligned} \tag{12'}$$

where $\vec{v}_k$ and $\vec{\varepsilon}_k$ are N dimensional vectors consisting of the velocities and errors at the points (t_μ, z_μ):

$$\vec{v}_k = \begin{vmatrix} v_k(t_1,z_1) \\ \\ v_k(t_\mu,z_\mu) \\ \\ v_k(t_N,z_N) \end{vmatrix} \qquad \vec{\varepsilon}_k = \begin{vmatrix} \varepsilon_k(t_1,z_1) \\ \\ \varepsilon_k(t_\mu,z_\mu) \\ \\ \varepsilon_k(t_N,z_N) \end{vmatrix} \quad k=1,2,3 \tag{12''}$$

$\mathcal{Z}$ is an N x p matrix with the μjth entry $Z_j(t_\mu, z_\mu)$. That is the jth column vector of $\mathcal{Z}$ consists of the jth approximation function $Z_j(t,z)$ evaluated at the N observation points (t_μ, z_μ).

$$\mathcal{Z} = \begin{vmatrix} Z_1(t_1,z_1) & \cdots & Z_j(t_1,z_1) & \cdots & Z_p(t_1,z_1) \\ Z_1(t_2,z_2) & & \vdots & & \vdots \\ \vdots & & \vdots & & \vdots \\ Z_1(t_\mu,z_\mu) & \cdots & Z_j(t_\mu,z_\mu) & & \vdots \\ \vdots & & & & \vdots \\ Z_1(t_N,z_N) & \cdots & \cdots & \cdots & Z_p(t_N,z_N) \end{vmatrix}_{N \times p} \quad (12''')$$

$\vec{\alpha}$, $\vec{\beta}$, and $\vec{\gamma}$ are p dimensional vectors composed of the unknown coefficients. (12') constitutes essentially three L S problems: determining the coefficient vectors $\vec{\alpha}$, $\vec{\beta}$, and $\vec{\gamma}$ such that the sums of the squares of the errors is minimized, i.e.: such that $\langle\vec{\varepsilon}_k, \vec{\varepsilon}_k\rangle$ is a minimum (where $\langle\vec{a},\vec{b}\rangle = \sum_i a_i b_i$). Also the errors are normally distributed with mean 0 and varience σ_k^2. That is $\vec{\varepsilon}_k$ is $N(0, \sigma_k^2 I)$ where I is the identity matrix.

Unfortunately, we do not have the observations of the individual velocity components v_k, but only random linear combinations of them. Substitution of (12) into (8) yields:

$$V_{L\mu} = d_{1\mu} \sum_{j=1}^{p} \alpha_j Z_j(t_\mu,z_\mu) + d_{2\mu} \sum_{j=1}^{p} \beta_j Z_j(t_\mu,z_\mu) + d_{3\mu} \sum_{j=1}^{p} \gamma_j Z_j(t_\mu,z_\mu)$$

$$+ (d_{1\mu}\, \varepsilon_1(t_\mu,z_\mu) + d_{2\mu}\, \varepsilon_2(t_\mu,z_\mu) + d_{3\mu}\, \varepsilon_3(t_\mu,z_\mu))\ \mu = 1,2, \ldots N \quad (13)$$

If we assume

$$\sigma_1^{\ 2} = \sigma_2^{\ 2} = \sigma_3^{\ 2} = \sigma^2 \tag{14}$$

We have:

$$V_{L\mu} = d_{1\mu} \sum_{j=1}^{p} \alpha_j Z_j(t_\mu, z_\mu) + d_{2\mu} \sum_{j=1}^{p} \beta_j Z_j(t_\mu, z_\mu)$$

$$+ d_{3\mu} \sum_{j=1}^{p} \gamma_j Z_j(t_\mu, z_\mu) + \varepsilon_\mu \qquad \mu = 1, 2, \ldots N \tag{15}$$

where ε_μ is $N(0, \sigma^2)$ since:

$$d_{1\mu}^2 \sigma_1^{\ 2} + d_{2\mu}^2 \sigma_2^{\ 2} + d_{3\mu} \sigma_3^{\ 2} = (d_{1\mu}^2 + d_{2\mu}^2 + d_{3\mu}^2)\sigma^2 = \sigma^2 \tag{15'}$$

More compactly,

$$\vec{V}_L = D_1 \mathcal{Z} \vec{\alpha} + D_2 \mathcal{Z} \vec{\beta} + D_3 \mathcal{Z} \vec{\gamma} + \vec{\varepsilon} \tag{16}$$

where

$$\vec{V}_L = \begin{vmatrix} V_{L1} \\ V_{L2} \\ \vdots \\ V_{L\mu} \\ \vdots \\ V_{LN} \end{vmatrix} \qquad D_k = \begin{vmatrix} d_{k1} & & & & \\ & d_{k2} & & & \\ & & \ddots & & \\ & & & d_{k\mu} & \\ & & & & d_{kN} \end{vmatrix}_{N \times N} \qquad k = 1,2,3 \tag{16'}$$

and $\vec{\varepsilon}$ is $N(0, \sigma^2 I)$. Or finally,

$$\vec{V}_L = \hat{\mathcal{Z}} \vec{\delta} + \vec{\varepsilon} \tag{17}$$

where:

$$\hat{\mathcal{Z}} = \left| D_1\mathcal{Z} \,\middle|\, D_2\mathcal{Z} \,\middle|\, D_3\mathcal{Z} \right|_{N \times 3p} \qquad \vec{\delta} = \begin{vmatrix} \vec{\alpha} \\ \hline \vec{\beta} \\ \hline \vec{\gamma} \end{vmatrix}_{3p \times 1} \tag{17'}$$

(17) is now in the form of the classical Least Squares Problem. The solution $\vec{\delta} = \vec{b}$ is the 3p dimensional vector of coefficients that makes $\vec{\varepsilon}$ N(0, σ^2I) with σ^2 minimized. The Gauss Markov Theorem states that $\vec{b}$ is a solution of this problem if it is a solution of the Normal Equations:

$$\hat{Z}^t \hat{Z} \vec{\delta} = \hat{Z}^t \vec{V}_L \tag{18}$$

In this case $\hat{Z}\vec{b}$ is a "best linear unbiased estimate" of $\vec{V}_L$, i.e.:

$$E[\hat{Z}\vec{b}] = \vec{V}_L$$

and

$$\sigma^2_{Z\vec{b}} = \min_{\vec{\delta}} \sigma^2_{Z\vec{\delta}}$$

where E [ ] is the expected value operator. The solution of (18), $\vec{b}$, yields the coefficient vectors $\vec{\alpha}$, $\vec{\beta}$, and $\vec{\gamma}$ and hence approximations of the velocity functions which are least squares in the sense of the observations of V_L - the line of sight velocities. The error that has been minimized is that between the linear combinations of the velocity approximations and the line of sight observations.

We must now choose the set of approximating functions: $\{Z_j\ (t,z)\}_{j=1}^{p}$. Criteria for these should be:

(i) They do not bias the spectral content of the velocities.

(ii) They do not require stationarity of the wind field.

(iii) The resulting approximation functions for $v_k(t,z)$ be sufficiently flexible to conform to the data, i.e.: the resolution of the velocity functions be limited by only the data.

We will choose as our set of approximating functions a "basis set" of functions for the collection or "space" of piecewise bicubic splines: $S(\Pi)$, over a given partition Π of the domain.

Consider a finite interval $[t_o, t_f]$ on the real line. The set of n + 1 uniformly spaced points: $\pi = \{t_i\}_{i=1}^{n+1}$ such that:

$$t_o = t_1 < t_2 < t_3 < \ldots\ldots < t_{n+1} = t_f$$

forms a uniform partition of the interval into n half open subintervals: $\{[t_i t_{i+1})\}_{i=1}^{n}$ (Fig. 6). Over this partitioned interval exists a space of functions: $S(\pi)$, consisting of all piecewise cubic splines with nodes at the points of the partition π. Contained in this space is a "basis set" of n + 3 linearly independent functions $\{\ell_j(t)\}_{j=1}^{n+3}$, from which any other function in the space may be constructed by linear superposition. Thus if $s(t) \varepsilon S(\pi)$, then

$$s(t) = \sum_{j=1}^{n+1} \alpha_j \, \ell_j(t) \tag{19}$$

for suitable choice of the coefficients α_j. The choice of the basis set for $S(\pi)$ is not unique. Our choice will be the so called "B splines" or "hump functions" (see DeBoor, 1972). Briefly, the B-splines have been chosen because they are local (no more than four of the basis functions are nonzero at any point), yielding fewer necessary computations and also they may be computed directly from a partition without solving additional linear systems.

First we augment the initial partition N by three points of each side of the interval and thus form the augmented partition $\hat{\pi} = \{t_i\}_{i=1}^{n+7}$ consisting of n + 6 sub-intervals (Fig. 7). The ith "normalized cubic B-spline" $N_i(t)$ is non-zero on the interval (t_i, t_{i+4}) (Fig. 8) and is given by:

$$N_i(t) = (t_{i+4} - t_i) \sum_{\nu=i}^{i+4} \frac{(t\nu - t)_+^3}{\prod_{\substack{j=i \\ j\neq\nu}}^{i+4} (t\nu - t_j)} \tag{20}$$

where

$$X_+^3 = \begin{cases} X^3 & X \geq 0 \\ 0 & X < 0 \end{cases} \tag{20'}$$

Then the set $\{N_i(t)\}_{i=1}^{n+3}$ comprises a bases set for $S(\pi)$ and thus any linear combination of these functions results in a piecewise cubic spline function.

Let us now return to the two-dimensional domain in the t-z plane: $[t_o,t_f) \times (z_o,z_f)$. Partitioning $[t_o,t_f)$ into n equilength half open subintervals and (z_o,z_f) into m equilength half open subintervals creates the partition $\Pi = \{(t_i,z_j)\}_{i=1}^{n}{}_{j=1}^{m}$ consisting of nm rectangles:

$$\{[t_i,t_{i+1}) \times [z_j,z_{j+1})\}_{i=1\ j=1}^{n\quad m} \text{(Fig. 9).}$$

This generates an augmented partition $\hat{\Pi} = \{(t_i,z_j)\}_{i=1\ j=1}^{n+7\ m+7}$ consisting of $(n + 6)(m + 6)$ subrectangles (Fig. 10).

Then as a basis of $S(\Pi)$, the space of all piecewise bicubic splines on Π, we choose the set of $(n + 3)(m + 3)$ functions: $\{N_i(t)\cdot N_j(z)\}_{i=1\ j=1}^{n+3\ m+3}$. Letting

$$Z_k(t,z) = N_i(t)\cdot N_j(z) \quad i=1,2, \ldots n+3,\ j=1,2, \ldots m+3$$
$$k=1,2, \ldots p \tag{21}$$

where

$$k = (j - 1)(n + 3) + i \tag{21'}$$

and

$$p = (n + 3)(m + 3) \tag{21''}$$

any linear combination

$$\sum_{k=1}^{p} \alpha_k Z_k(t,z)$$

will result in a piecewise bicubic spline in the domain with partition Π. Notice that for any k, $Z_k(t,z)$ is nonzero in only 16 subrectangles. Similarly the localness of $Z_k(t,z)$ implies that for any $(t,z) \in [t_i, t_{i+1}) X[z_j, z_{j+1})$ There will be at most 16 $Z_k(t,z)$ which are nonzero at this point:

$$
\begin{array}{ll}
Z_k(t,z) & (j - 1)(n + 3) + (i - 3) \leq K \leq (j - 1)(n + 3) + i \\
Z_k(t,z) & (j - 2)(n + 3) + (i - 3) \leq K \leq (j - 2)(n + 3) + i \\
Z_k(t,z) & (j - 3)(n + 3) + (i - 3) \leq K \leq (j - 3)(n + 3) + i \\
Z_k(t,z) & (j - 4)(n + 3) + (i - 3) \leq K \leq (j - 4)(n + 3) + i
\end{array}
\tag{22}
$$

Returning to the Least Squares Problem, we now choose as our set of approximating functions this basis set of $p = (n + 3)(m + 3)$ functions on $S(\Pi)$, i.e. $\{Z_j(t,z)\}_{j=1}^{p}$. We may then construct the matrix $\mathcal{Z}$ whose jth column vector consists of the jth basis function $Z_j(t,z)$ evaluated at the N points (t_μ, z_μ). Equivalently the μth row will consist of the p basis functions evaluated at the point (t_μ, z_μ) - there will be at most only 16 nonzero entries given by (22). Having $\mathcal{Z}$ we may construct $\hat{\mathcal{Z}}$ given by (17'), and then proceed to solve the normal equations (18). The solution of (18) then yields approximates for $v_k(t,z)$ which as previously discussed are piecewise bicubic polynomials over subrectangles of the partition Π and which are such that the error in the line of sight observations is minimized. The normal equations are particularly well suited for numerical solution in that the resulting coefficient matrix, $\hat{\mathcal{Z}}^t\hat{\mathcal{Z}}$, is symmetric positive definite. This implies a greater degree of stability for large systems.

3. Test Results

Initially the method was tested with the following known input functions:

$$\begin{cases} v_1(t,z) = \sin(4\pi t) \\ v_2(t,z) = \sin(\pi z) \\ v_3(t,z) = (t + z)^3 \end{cases} \tag{23}$$

with (t,z) in the unit square. Observation points were selected randomly (uniform in t and z) as were the corresponding direction cosines. The solution remained stable for different ensembles of observation points. It also remained stable for different ratios of the number of observations to the number of unknowns being determined: N/3p. For fixed ensemble of observations, different partitions, i.e.: different temporal and vertical mesh sizes n and m, were used. For almost all partitions the resulting approximation functions for $v_k(t,z)$ represented the true (known) function quite well.

Figure 11 shows a plot of the variance of known values of $v_1(t,z)$ about the approximate values as a function of temporal mesh size n (for m = 1) and the ratio N/3p. Also shown are the variences of V_L about the approximate values. It can be seen that for increasing partition number the resulting variences of the velocity functions v_k and V_L decrease to quite acceptable values except possibly at even values of n. This may be related to the fact that the spline functions used were cubic. Also as n increases past the value where N/3p < 1.63 the variances of the velocity functions v_k starts increasing while the varience of V_L decreases monotonically to zero. The ratio N/3p may be considered as a measure of the overspecification of the problem. Thus as N/3p tends to unity the linear problem becomes determinate. However Figure 11 indicates that although $\sigma_{V_L}^2$ tends to zero as N/3p tends to one, $\sigma_{v_k}^2$ grows arbitrarally large.

This is consistent with the development since it is $\sigma_{V_L}{}^2$ which is being minimized, and only through the excess of constraints do we achieve small values for $\sigma_{v_k}{}^2$. That is as N/3p tends to unity the "data points" $V_{L\mu}$ are interpolated exactly, but the "decomposition" of v_k is lost. This minimum usable ratio of N/3p = 1.63, although expected to vary with the data, compares favorably with a corresponding ratio of 3 or 4 that has been found from experience to yield reasonable results in the Groves Analysis.

Similar results are shown in Figures 12 and 13 for different choices of $v_k(t,z)$. In virtually all cases examined the majority of the varience could be traced to regions of the domain where there was an absence or sparse scatter of data points, (t_μ,z_μ). In such regions, the resulting approximation functions are relatively unconstrained and may behave in essentially whatever manner needed in order to better fit the data where it occurs in greater abundance.

In particular if an <u>interior</u> region of the domain has a low data density, i.e.: few sample points (t_μ,z_μ) the resulting approximation is quite well behaved in this region and seems to vary "naturally" with the functions in the rest of the domain. The region is surrounded by constraints (observation points $V_L(t_\mu,z_\mu)$). These constraints "project" the behavior of the velocity functions into this region. On the other hand if a region adjacent to the boundary of the domain is poorly constrained, the approximation functions in this region may grow unreasonably large. Recall for the one-dimensional domain, a spline is a series of coupled polynomials over adjacent intervals, where each polynomial is used only over one of the intervals (Fig. 14). In general cubic polynomials diverge as x tends to $\pm\infty$. Thus each of the polynomials used in the spline does diverge, but not in the interval of use. Consider the outermost intervals. If the spline elements over these intervals are not constrained sufficiently, they need only meet additional constraints from one side - towards the interior of the partition. Thus we might expect the polynomials to grow quite large near the end points in order that the interior spline better fit the data where it occurs in greater abundance. A similar argument holds for the two-dimensional domain.

Finally, Figure 12 indicates a relatively large value of $\sigma_{v_1}^{\ 2}$ for n = 1. Since over any subrectangle the approximate functions may vary at most as a cubic polynomial along either axis, and since a cubic has at most two critical points, we should not expect good representation of trigonometric functions having more than one cycle over any one rectangle. This has particular significance to the spectral resolution of this decomposition. In general, we should not expect spectral content of frequencies having more than one cycle per partition interval. Indeed, this has been verified by all of the cases examined. Thus Figure 12 indicates the approximation functions for n = 1 are incapable of adequately conforming to two cycles contained in the v_1 velocity function. It is important to note that $\sigma_{v_2}^{\ 2}$ and $\sigma_{v_3}^{\ 2}$ remain relatively low at the same time, indicating they are essentially unaffected by the inability to conform to v_1. As the partition number n is increased, the approximation function gains additional degrees of freedom and is better able to conform to the data. For n = 2, $\sigma_{v_1}^{\ 2}$ has decreased greatly, and by n = 3 it is quite small.

Thus we have solved the problem with reasonably good success over a given domain in the t-z plane - a strip of length T. The resolution in t and z of the decomposed functions $v_k(t,z)$ (i.e. the size of the partition Π) is limited by:

i) the number of observations N.

ii) the uniformity of the observation points (t_μ, z_μ) in the domain - if there are gaps or holes in the domain where there are few observations, in particular near the boundaries, a cruder partition must be used.

iii) computational capabilities - the number of unknowns being solved for simultaneously (size of the linear system) is of course limited by the machine used.

The last of these implies that a compromise must be reached between degree of resolution (partition size) and size of the domain being examined. Since ultimately, long time series are to be examined, this technique would be of little value if the resolution was lost. We now explore a method of attaining high resolution in the approximations of $v_k(t,z)$ over adjacent strips of suitable length - say T, and coupling the function over these domains.

Consider a strip in the t-z plane of length 3T, width $z_f - z_o$ (Fig. 15). First we divide this region into three substrips each of length T. If the data were decomposed over disjoint strips, the resulting velocity approximates would be uncoupled. For many purposes, if there is sufficient data, this would probably be adequate. In order to couple these strips, we increment each by an amount ΔT on both sides, i.e.

$$[t_o, t_o + T) \rightarrow [t_o - \Delta T, t_o + T + \Delta T).$$

$$[t_o + T, t_o + 2T) \rightarrow [t_o + T - \Delta T, t_o + 2T + \Delta T)$$

$$[t_o + 2T, t_o + 3T) \rightarrow [t_o + 2T - \Delta T, t_o + 3T + \Delta T)$$

The data is then decomposed on the first "augmented" strip, but the resulting velocity functions are retained only over the smaller strip of length T. If this is done with all the strips the regions used to produce the approximations will overlap, and thus information is fed both forwards and backwards. Moreover, continuity (in a least squares sense) may be obtained by actually producing data points at the interfaces of the regions from the approximation functions of the previously analyzed region (Fig. 15). The procedure just outlined not only couples adjacent domains, but also eliminates undesirable behavior near portions of the boundaries of these domains due to insufficient data. The resulting approximates for $v_k(t,z)$ represent the "instantaneous" wind field. Of course adjacent sampling periods may be superimposed, as in other techniques, to yield a higher data density thereby increasing the resolution, but at the expense of the spectral content at non window periodic frequencies. The resulting approximations would then represent some "average sense" wind field.

The following set of test functions was then used on the strip given by $\{(t,z): t \in [0,3),\ z \in [0,1)\}$

$$v_1(t,z) = \sin(3\pi t) + \sin(4\pi t)$$

$$v_2(t,z) = \sin(\pi z)$$

$$v_3(t,z) = (t + z)^3$$

The domain was divided into three substrips each of length T = 1; 300 data points were randomly scattered on each. The decomposition was performed as previously discussed- but without projecting data points into adjacent regions to achieve continuity. Figure 16 shows approximation values of $v_1(t, 2/3)$ for m = 1, n = 1,3,5. Figure 17 shows the actual input function $v_1(t,2/3)$. As previously discussed, the approximation functions for n = 1 cannot conform to the variation of $v_1(t,z)$ over any interval. This is primarially responsible for the discontinuities between the strips at t = 2. It is interesting to note that despite this handicap, the approximation for n = 1 does indicate the general trend. Approximation for n = 3 and n = 5 are both very close to the true behavior of $v_1(t,2/3)$. Recall that the information of this behavior comes from randomly scattered points throughout the domain and was imbedded in the behavior of $v_2(t,z)$ and $v_3(t,z)$.

Figure 18 shows the corresponding power spectrum of these time series. The spectrum for $n = 1$ has peaks at the correct frequencies, but the discontinuities have introduced noise throughout the spectrum. This is evidenced greatest by the higher frequency content, which this spline approximation is incapable of producing. Spectra for $n = 3$ and $n = 5$ are essentially identical with the true spectrum shown in Figure 19.

We now perform a similar decomposition: $v_2(t,z)$ and $v_3(t,z)$ are as before, but now allow $v_1(t,z)$ to have two widely separated spectral components (as may be expected in a true wind field):

$$v_1(t,z) = \sin(2\pi t) + \sin(12\pi t)$$

The approximation for $n = 3$ and the true behavior of $v_1(t,1/2)$ are shown in Figure 20. Again the approximation is incapable of conforming to 6 cycles over any strip of length $T = 1$. Yet aside from the discontinuities at the boundary points: $t = 1$ and $t = 2$ (data points were not projected into adjacent regions), the approximation is the one most desirable - it indicates the general trend of $v_1(t,1/2)$. The associated spectra reenforce this (Fig. 21). Except for the peak missing at the higher unattainable frequency, the predicted spectrum is very close to the true spectrum. Even without projecting data points into adjacent regions, the discontinuities are not excessive and produce only a very small amount of noise in the spectrum. This is very important, not only is the decomposition spectrally unbiased, but also this indicates that inability of the approximation functions to represent higher frequency content of the velocity field (as will surely be the case in actual wind data) does not distort the spectrum at frequencies that can be represented.

It should be noted that when used on actual data, the only means of evaluating the error in the approximation is relative to the observations in V_L, i.e.: linear combinations of the $v_k(t,z)$. Even this may be quite large. In the previous example, where a large portion of the spectral content was unrepresentable, $\sigma_{v_1}{}^2$ was .97 or roughly 50% of the maximum value achieved by $v_1(t,z)$. Despite this, the approximation yields the appropriate trend. In general, we expect the true wind field to have contributions (possibly quite substantial) from frequencies that neither the observations nor the approximations are able to resolve. Therefore the varience of the data about the approximation, $\sigma_{v_L}{}^2$, is a questionnable criteria for the reliability of the approximation.

4. Final Results

The finite element method was used to decompose meteor wind data taken at Georgia Tech over the 8 day period from July 19, 1975 to July 26, 1975. The height range considered was from 70 km to 120 km.

The period was divided into 8 one-day strips, each of which was augmented by 8 hours on either side and then partitioned into 7 intervals along the time axis and 1 along the vertical (i.e.: $T = 24$ hr, $\Delta T = 8$ hr, $n = 7$, $m = 1$). Thus we expect no spectral resolution of periods shorter than roughly 40/7 or 5.7 hr. A typical time trace of the resulting approximation $v_1(t, 100\text{ km})$, is shown in Figure 22. Figures 23 - 25 show power spectra for the three velocity components at the heights 80, 90, and 100 km. There is marked spectral content at 24, 12, and 8 hrs., but there are also striking features in the vicinities of 96, 48, 32, 19.2 and 13.7 hrs. The total velocity power spectrum was attained by adding the power spectra for the three components. These are shown in Figure 26 for the three heights considered. Among other features, the spectral content in the vicinity of 24 hours seems to increase monotonically with height (see Roper 1972). The 12 and 32 hr. contributions are also striking.

A sequence of hourly vertical profiles for $v_1(t,z)$ on July 20, appears in Figure 27. These were obtained with a vertical partition number of 3 ($m = 3$, $n = 7$). Notice the rapid development in the hours near sunrise. There seems to be some phase progression during the daylight hours, with the profiles tending to one uniform in z near the maximum daylight hours. The early evening hours indicate a return to increased variability with height.

5. Concluding Remarks

A method for decomposing radio meteor wind data into representations of the individual velocity components has been introduced and demonstrated. The technique was shown to be spectrally unbiased and limited in resolution essentially only by the data. Obviously there are areas in which this method may be refined. For example, use of different variences for the velocity components, nonuniform partitions giving higher resolution where the data permits, and different partitions for the different velocity functions. The least squares problem might also be posed in an integral or average sense (see Schultz pp. 76).

Acknowledgements

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List of Figures

Fig. 11: Variances of the True Velocities about their Approximations v_s, temporal Partition Number n and Overspecification Ratio N/3P (m = 1). As the Problem Approaches Determinancy $N/3P \to 1$, the variance of the Line of Sight Velocity (bottom): $\sigma_{V^2 L} \to 0$, but the Variances of the Individual Components (top) grows unreasonably large; $\sigma_V{}^2{}_k \to \infty$. $v_1 = \sin(4\pi t)$ $v_2 = \sin(\pi z)$ $v_3 = (t + z)^3$.

Fig. 12: As for Fig. 11 with $v_1 = \sin(3\pi t) + \sin(4\pi t)$, $v_2 = \sin(\pi z)$, $v_3 = (t + z)^3$.

Fig. 13: As for Fig. 11 with $v_1 = e^{-t} \sin(4\pi t)$, $v_2 = \sin(\pi z)$, $v_3 = (t + z)^3$.

Fig. 14: Spline Functions are Composed of pieces of Different Polynomials on Finite Intervals, each of which eventually diverges Outside the Interval it is used. If the Spline is Poorly Constrained in an interior Interval it must still meet constraints on Both Sides and hence should remain well behaved. However, if Poorly Constrained on a Boundary Interval the spline need only meet Constraints from One Side and therefore may Grow Unreasonably Large over the Interval it is used.

Fig. 15: Adjacent Time Periods of length T may be Coupled by Extending each temporally on both sides by ΔT so that they all overlap. Data over these Extended Domains is then Decomposed but the Resulting Velocity Functions are Retained only Over the Original Periods of Length T. Continuity between these Periods (in a Least Squares Sense), may be achieved by Producing Data Points, along the border Between the Strips of Length T, from the Velocity Functions Resulting from Decomposition of the Previous Period. Thus Adjacent Domains will have data points in the Overlapping Regions in common, and in Particular along the Border between the Domains.

Fig. 16: Approximation for $v_1(t, 2/3)$ for n = 1,3,5; m = 1. The Spline for n = 1 lacks sufficient flexibility to conform to the Input Function and a Discontinuity Results at t = 2. (No attempt was made to achieve "Least Squares Sense" Continuity at the Borders between the Regions). Despite this, the Appropriate Trend is indicated. Approximations for n = 3 and n = 5 are nearly Identical and the Discontinuity at t = 2 Disappears.

Fig. 17: Actual Input Function $v_1(t, 2/3) = \sin(3\pi t) + \sin(4\pi t)$.

Fig. 18: Power Spectra of Approximations for $v_1(t, 2/3)$ for Temporal Partition Numbers n = 1,3, and 5. Broad Band Noise for n = 1 Primarially due to Substantial Discontinuity see Fig. 17. Power Spectra for n = 3 and 5 are Essentially Identical and Identical with the Power Spectrum of the Actual Input Function, see Fig. 19.

Fig. 19: Power Spectrum of the Actual Input Function $v_1 = \sin(4\pi t) + \sin(3\pi t)$. (Two Distinct Spikes do not occur because one of the Input Frequencies lies between the Two Adjacent Frequencies of the Spectrum for the Sample Period T Used).

Fig. 20: Actual and Approximate Values for $v_1(t, 1/2)$. Actual Input Function $v_1 = \sin(2\pi t) + \sin(12\pi t)$; Temporal Partition Number $n = 3$; Aside from the Small Discontinuities at the Borders Between the Periods of Length 1, the Approximation indicates the Appropriate Trend Over the Periods, despite the fact that it is Incapable ($n = 3$) of Conforming to the True Input Function.

Fig. 21: Power Spectra of Actual and Approximate ($n = 3$) Velocity Function $v_1(t, 1/2)$. The Spectrum of the Approximate Function is very close to that of the True Function except for the Higher Frequency Spike which the Approximation is Incapable of Reproducing.

Fig. 22: Approximation for Zonal Velocity v_1 at $z = 100$ km over 8 Day Sample Period: July 19 - July 26, 1975.

Fig. 23: Power Spectra of Zonal Velocity Approximation $v_1(t,z)$ at the Heights 80, 90, and 100 km for the Period July 19 - July 26, 1975.

Fig. 24: Power Spectra of Meridional Velocity Approximations $v_2(t,z)$ at the Heights 80, 90, and 100 km for the Period July 19- July 26, 1975.

Fig. 25: Power Spectra of Vertical Velocity Approximations $v_3(t,z)$ at the Heights 80, 90, and 100 km for the Period July 19 - July 26, 1975.

Fig. 26: Total Velocity Power Spectra at the Heights 80, 90, and 100 km for the Period July 19 - July 26, 1975.

Fig. 27: Hourly Zonal Velocity Profiles for the Height Range 82.5 - 117.5 km during the Period 0500 - 2000 EST July 20, 1975. The Sequence was Obtained using the partition given by $n = 7$, $m = 3$; $T = 24$ Hr.

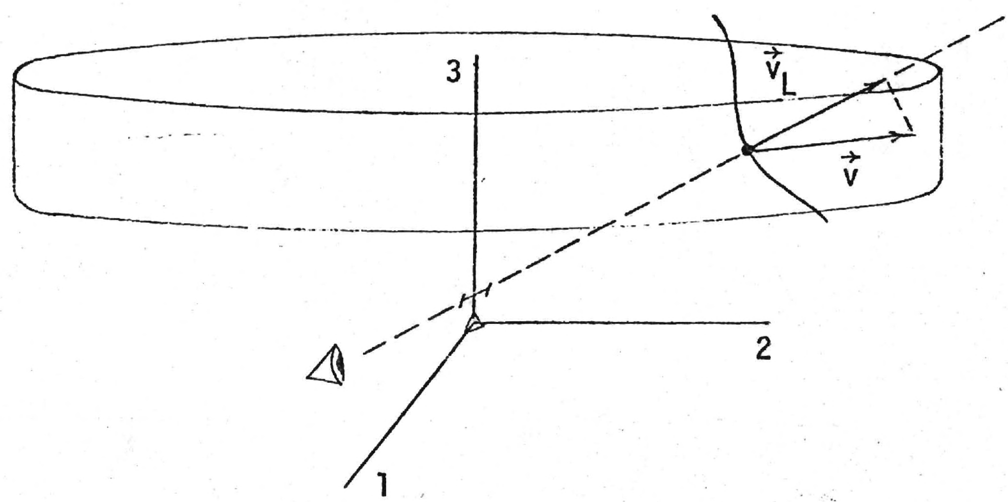


FIG 1

2

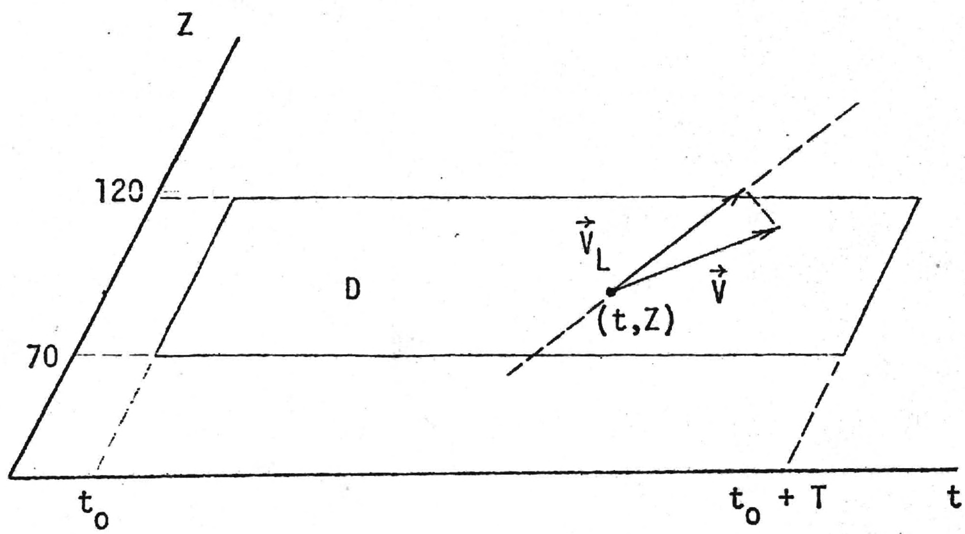


FIG 2

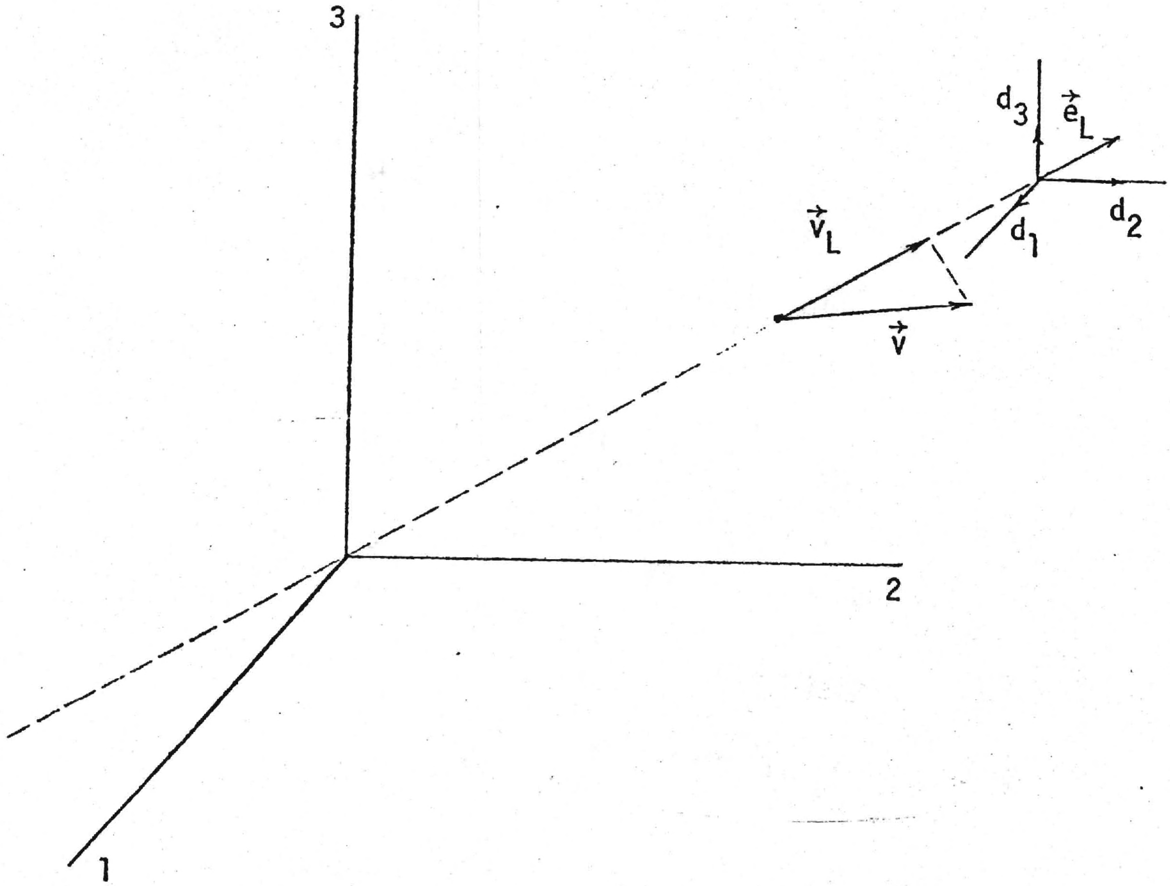


FIG 3

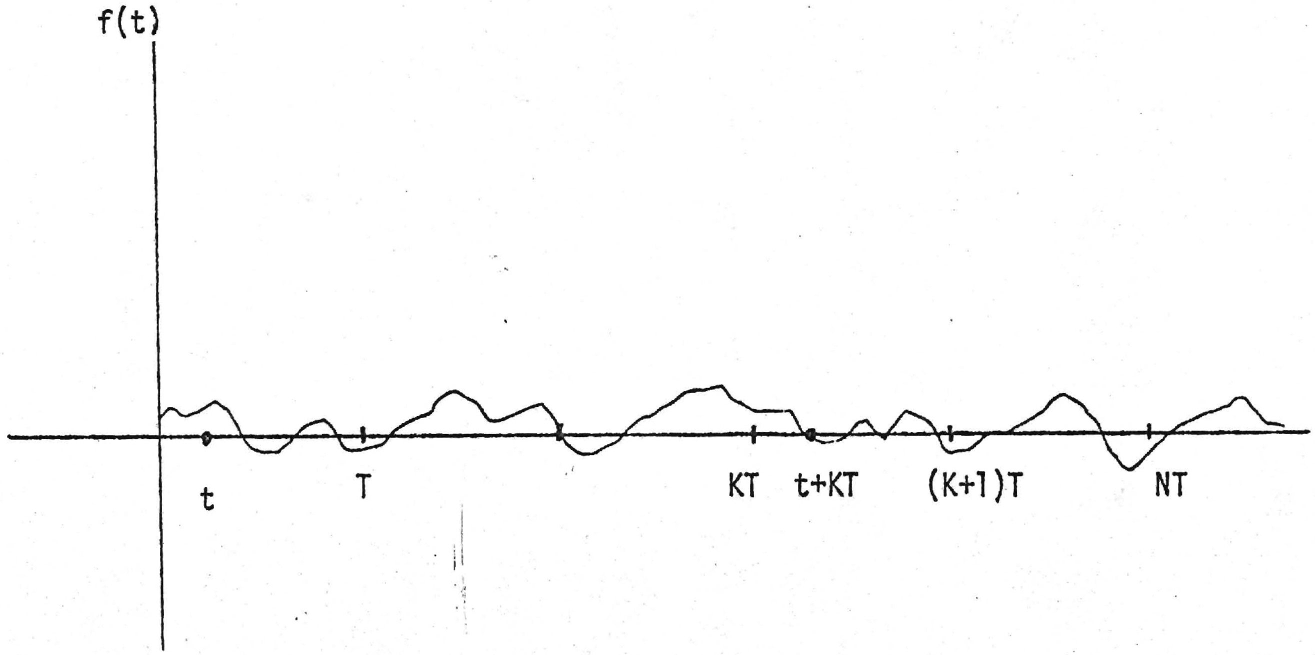


FIG 4

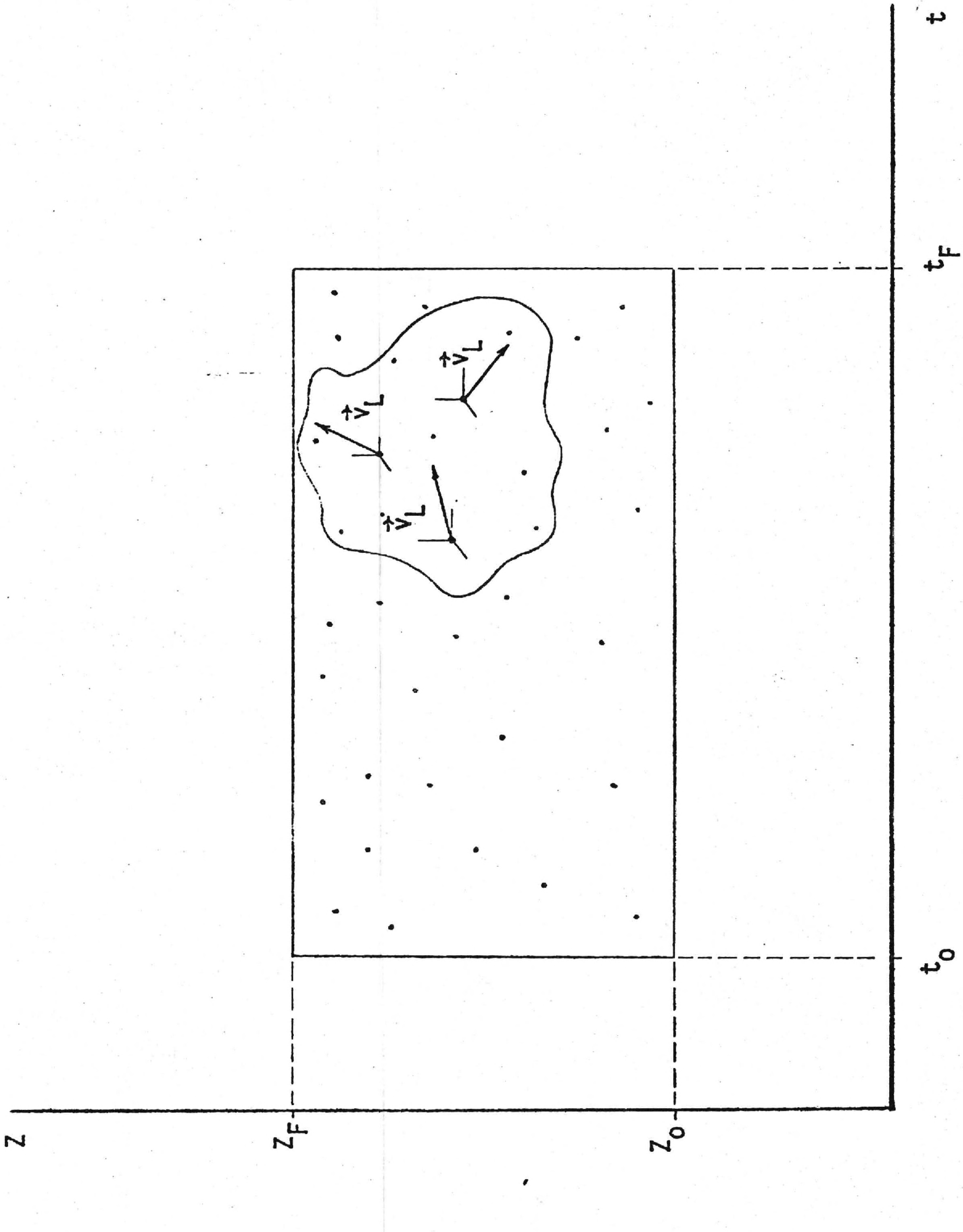


FIG 5

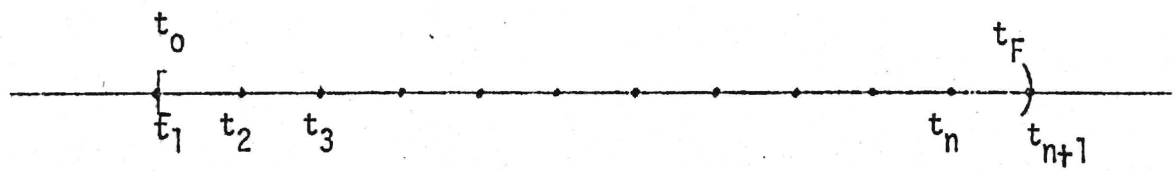


FIG 6

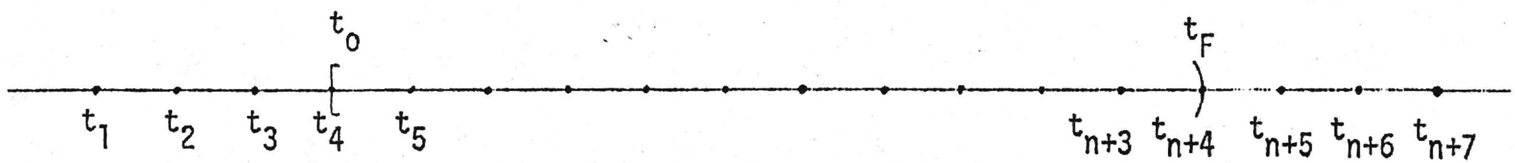


FIG 17

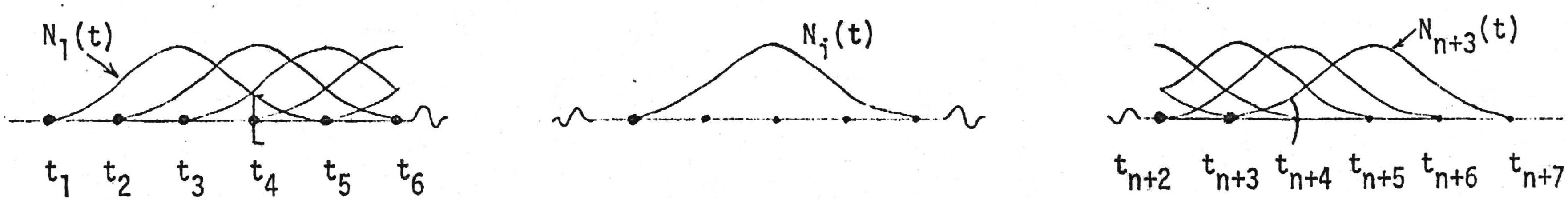


Fig 8

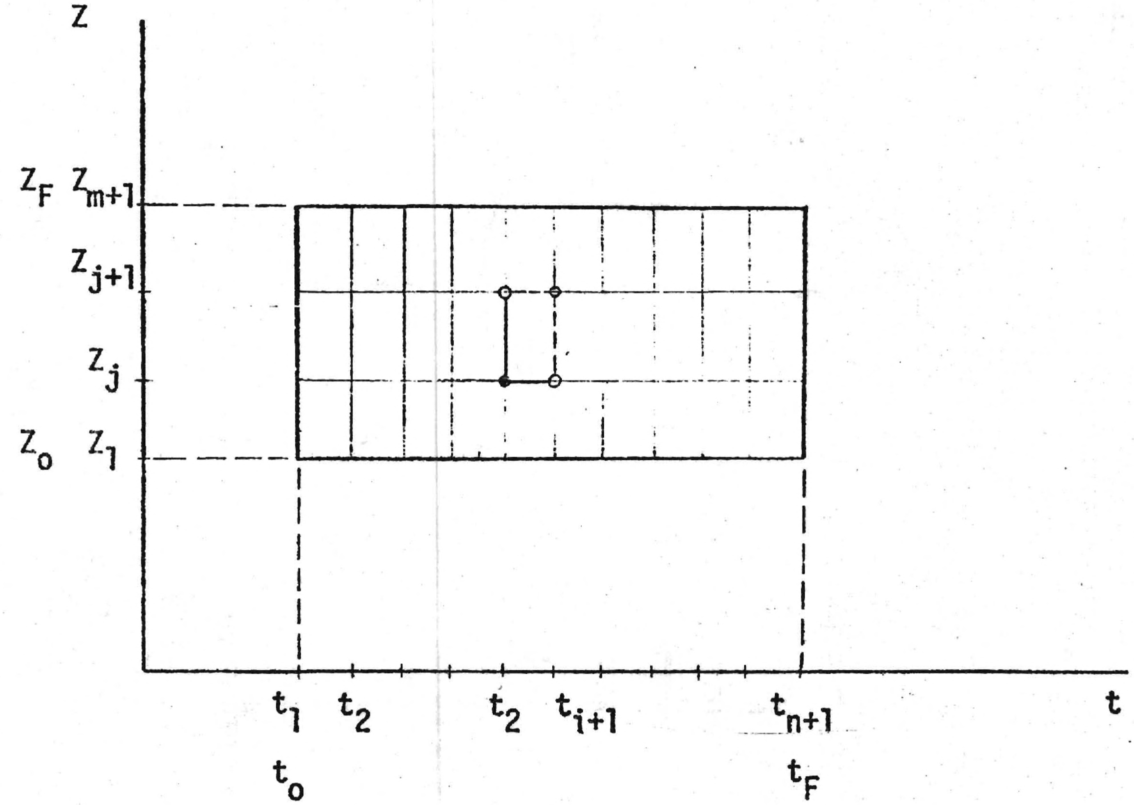
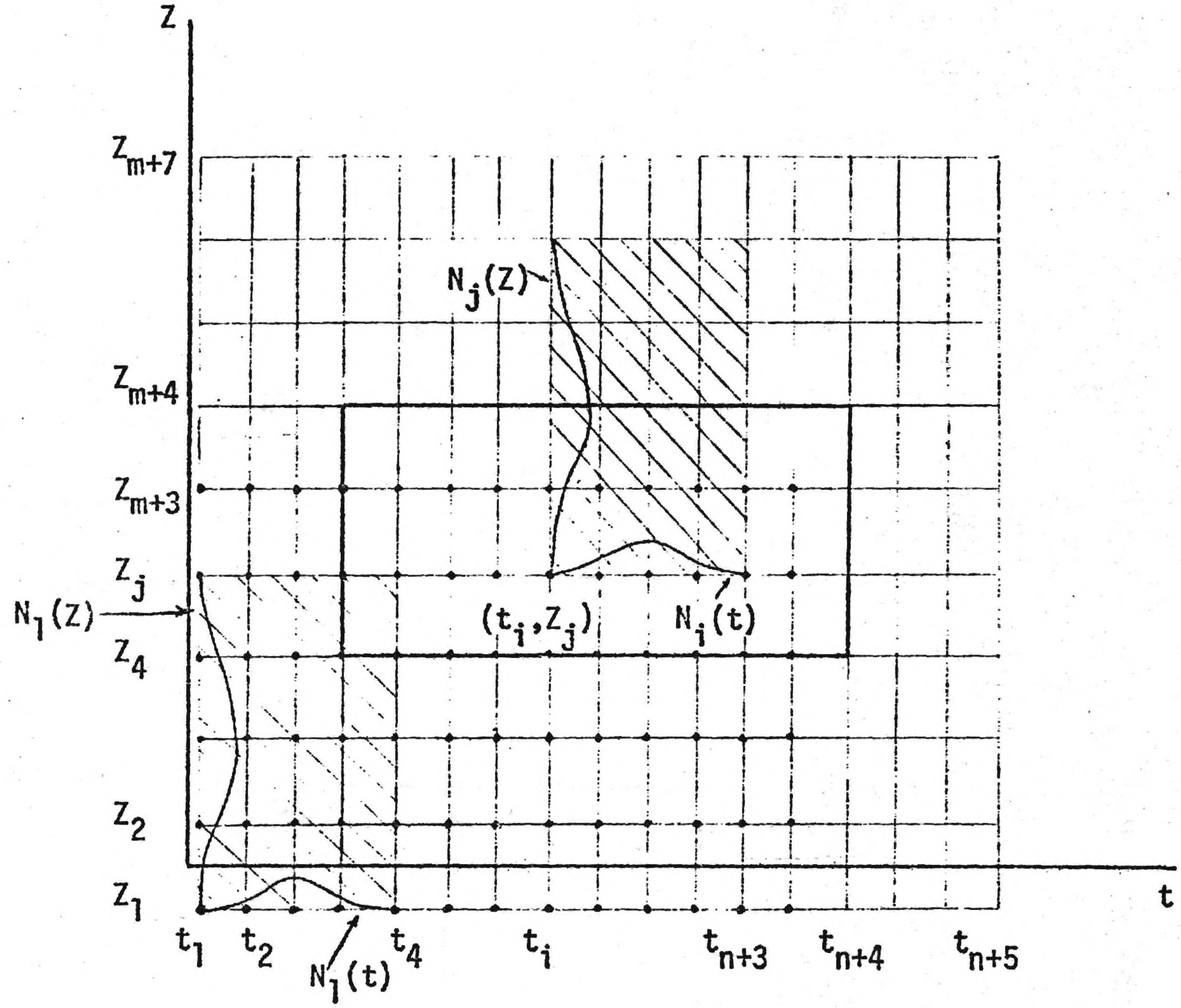


FIG 9


Z
Zm+7
Nj(Z)
Zm+4
Zm+3
Zj
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(ti,Zj)
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t2
N1(t)
t4
ti
tn+3
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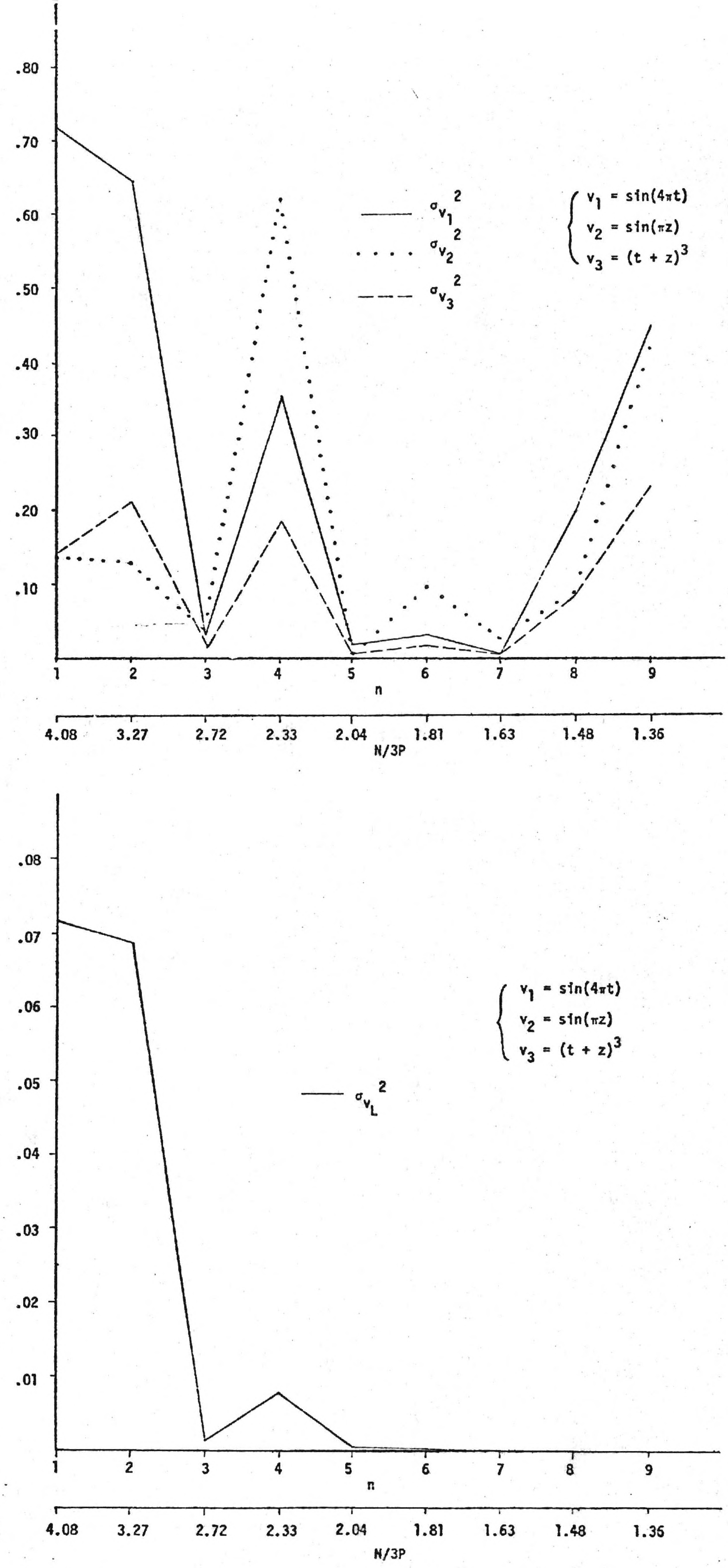
tn+5

FIG 10



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$\sigma_{v_2}^2$
$\sigma_{v_3}^2$
$v_1 = \sin(4\pi t)$
$v_2 = \sin(\pi z)$
$v_3 = (t + z)^3$
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n
4.08 3.27 2.72 2.33 2.04 1.81 1.63 1.48 1.36
N/3P
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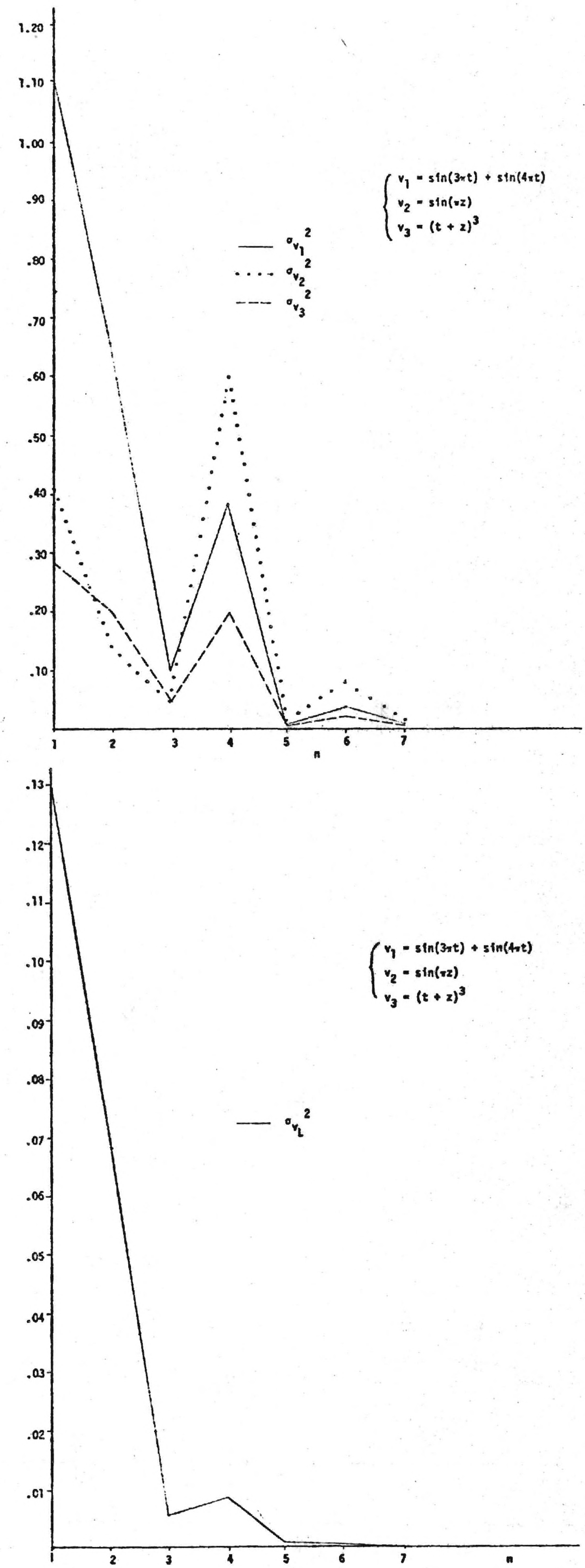
.07
.06
.05
.04
.03
.02
.01
$v_1 = \sin(4\pi t)$
$v_2 = \sin(\pi z)$
$v_3 = (t + z)^3$
$\sigma_{v_L}^2$
1 2 3 4 5 6 7 8 9
n
4.08 3.27 2.72 2.33 2.04 1.81 1.63 1.48 1.36
N/3P

FIG 11

12



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$v_1 = \sin(3\pi t) + \sin(4\pi t)$
$v_2 = \sin(\pi z)$
$v_3 = (t + z)^3$
$\sigma_{v_1}^2$
$\sigma_{v_2}^2$
$\sigma_{v_3}^2$
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$v_1 = \sin(3\pi t) + \sin(4\pi t)$
$v_2 = \sin(\pi z)$
$v_3 = (t + z)^3$
$\sigma_{v_L}^2$
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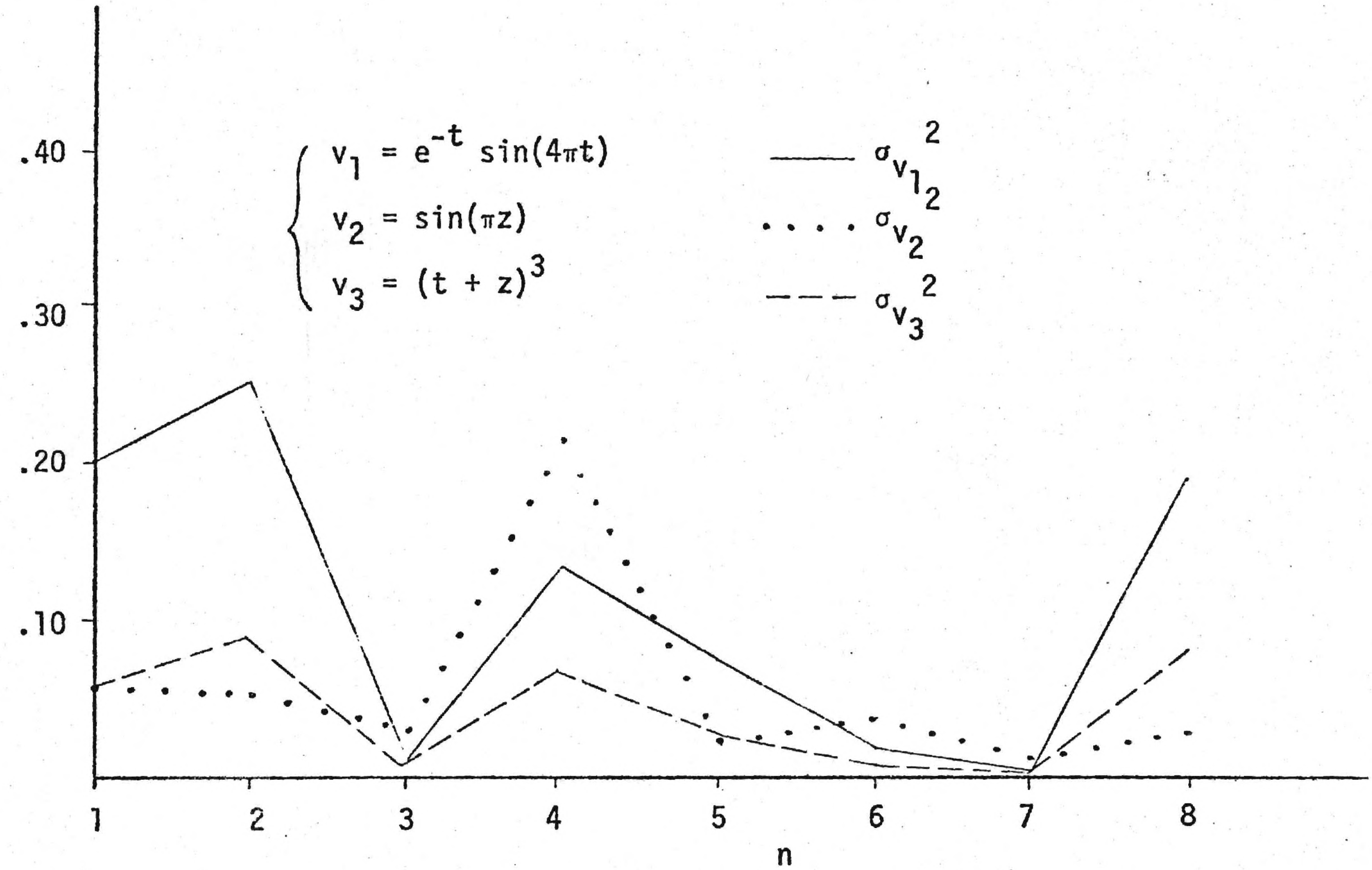
n

FIG 12



.40
.30
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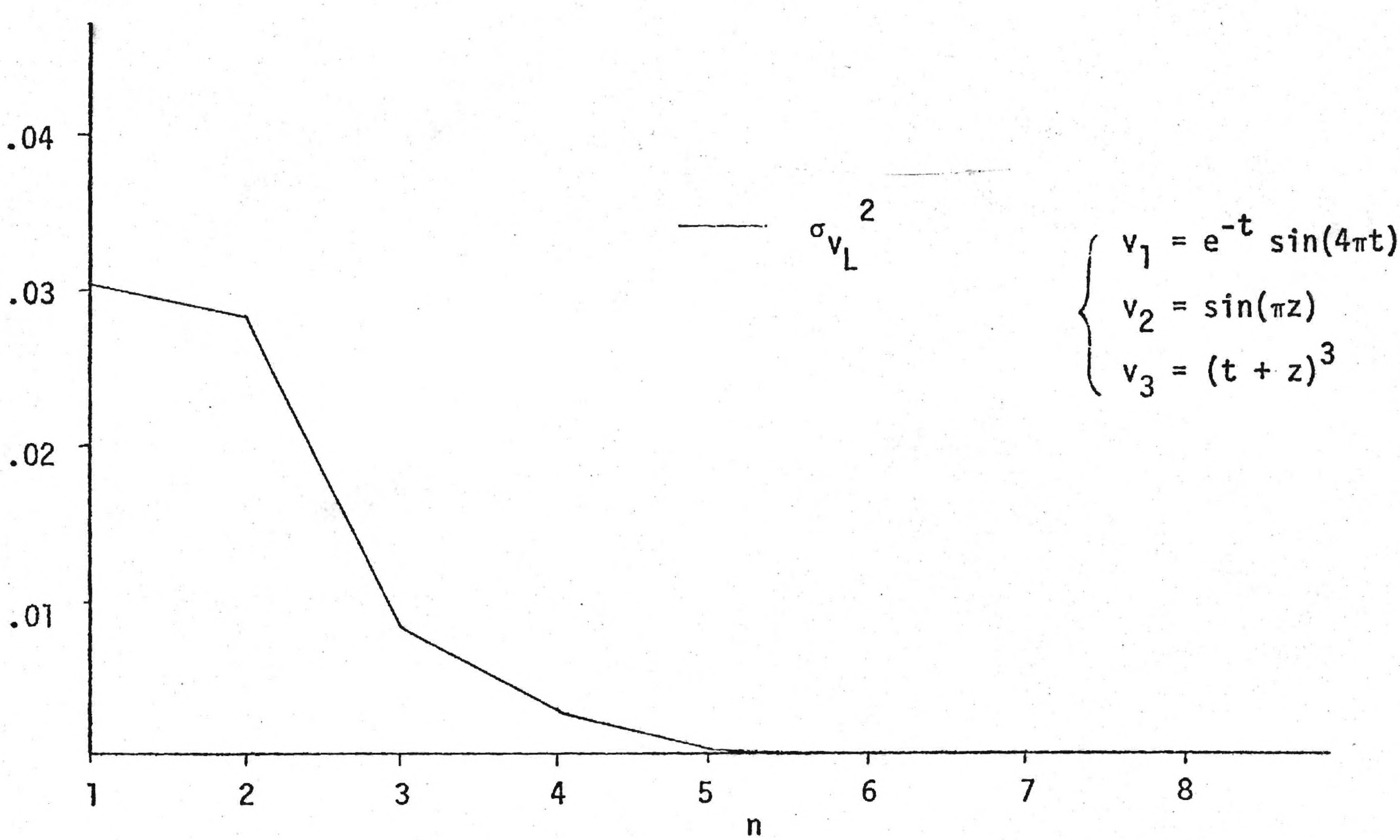
$v_1 = e^{-t} \sin(4\pi t)$
$v_2 = \sin(\pi z)$
$v_3 = (t + z)^3$
$\sigma_{v_1}^2$
$\sigma_{v_2}^2$
$\sigma_{v_3}^2$
1 2 3 4 5 6 7 8
n



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$\sigma_{v_L}^2$
$v_1 = e^{-t} \sin(4\pi t)$
$v_2 = \sin(\pi z)$
$v_3 = (t + z)^3$
1 2 3 4 5 6 7 8
n

FIG 13

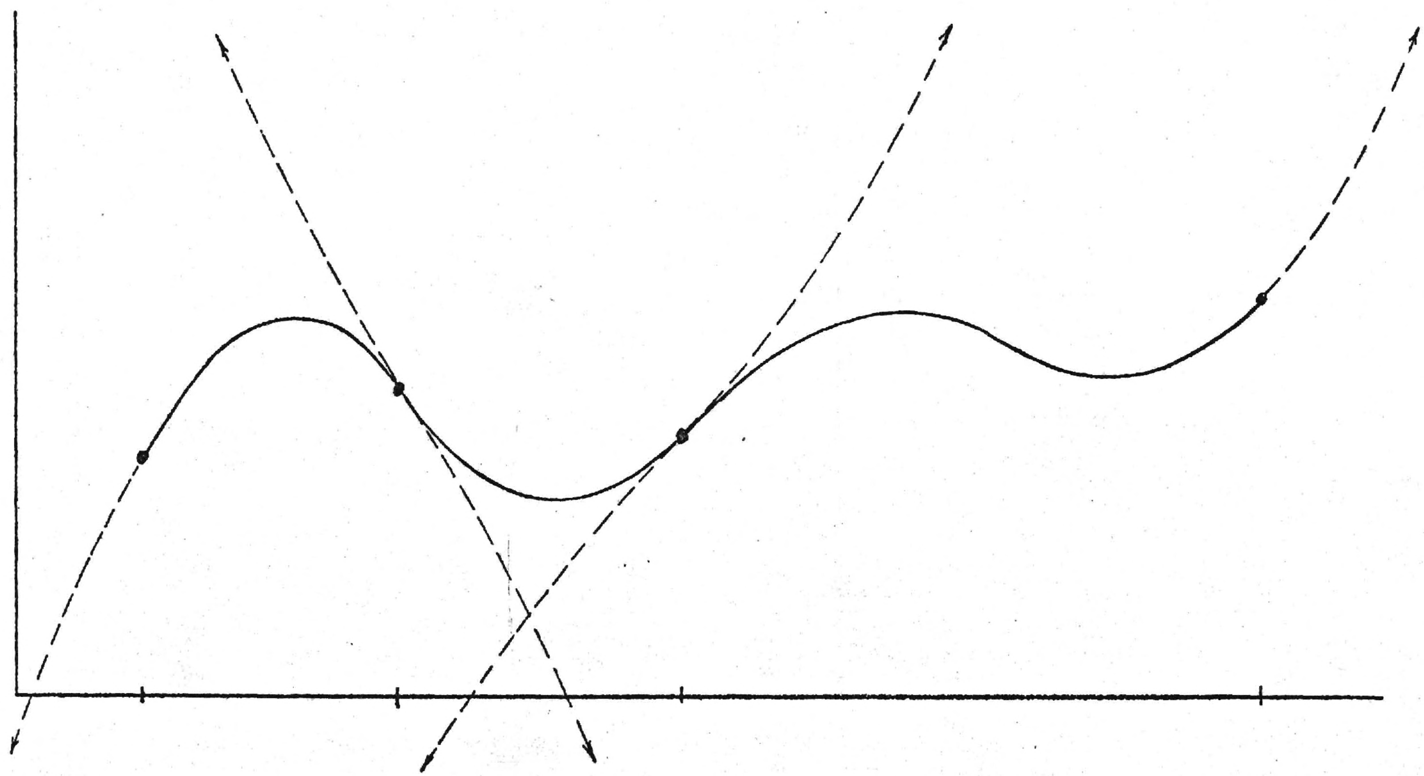


FIG 14

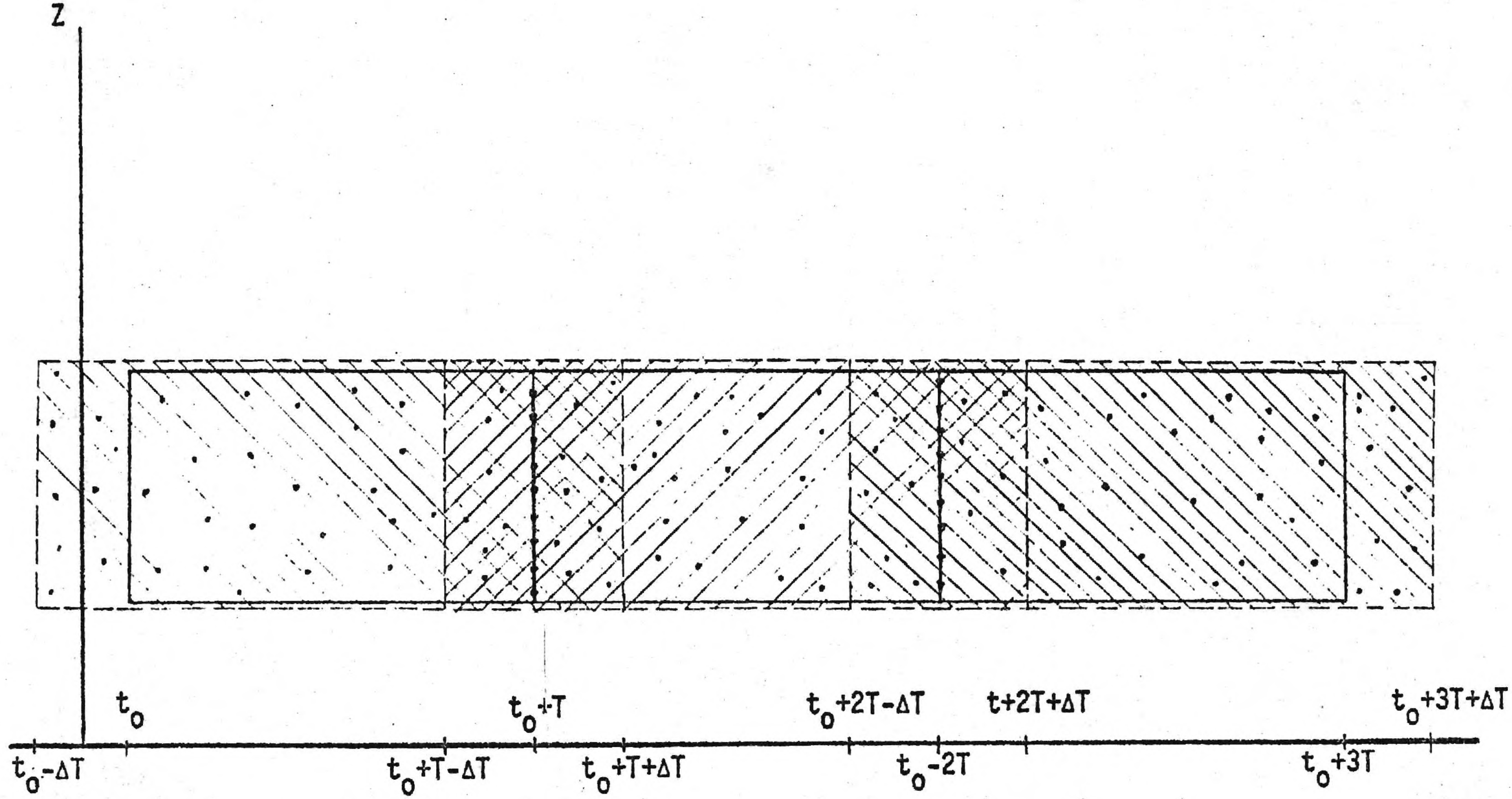


FIG 15

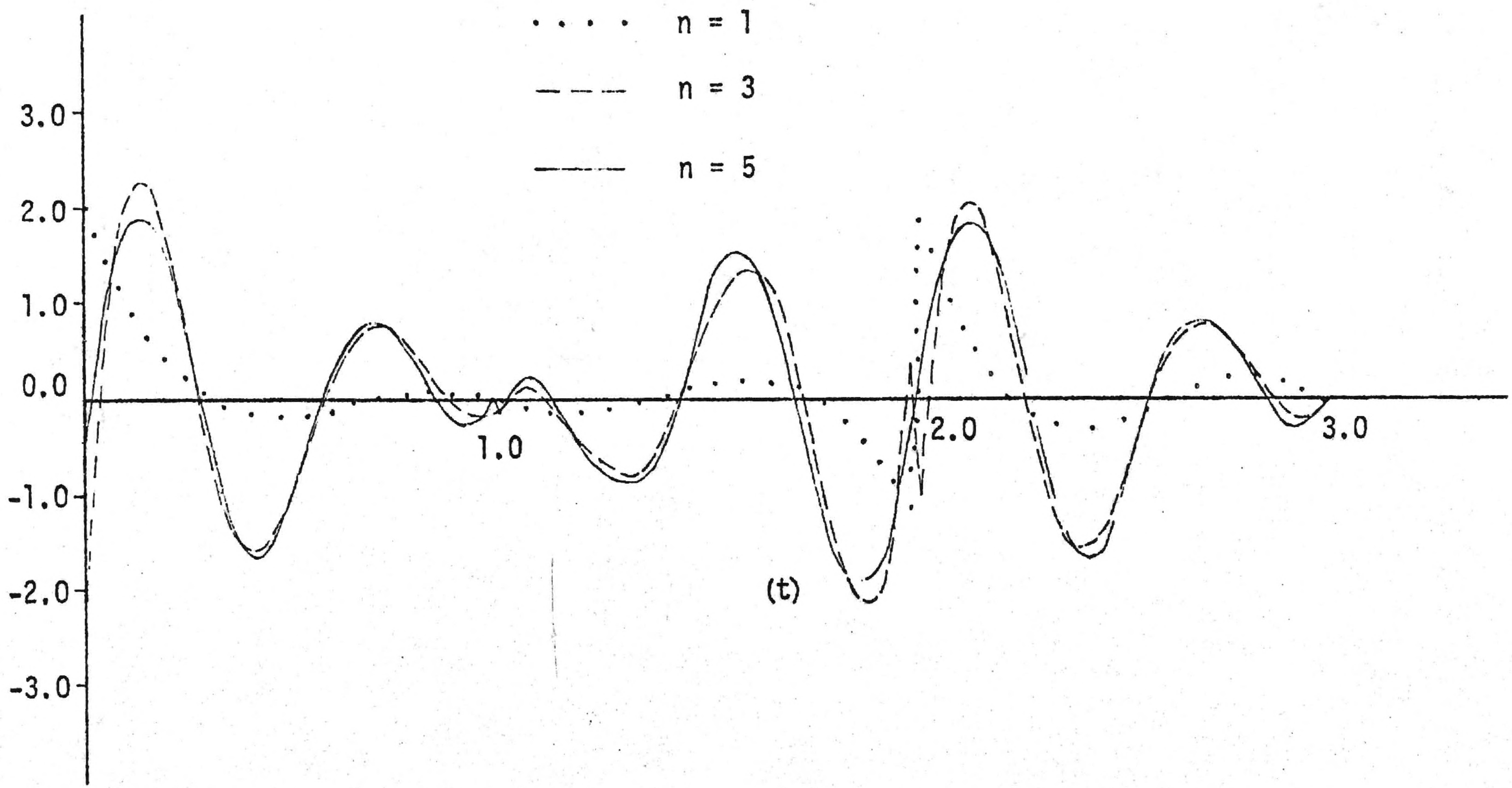


FIG 16

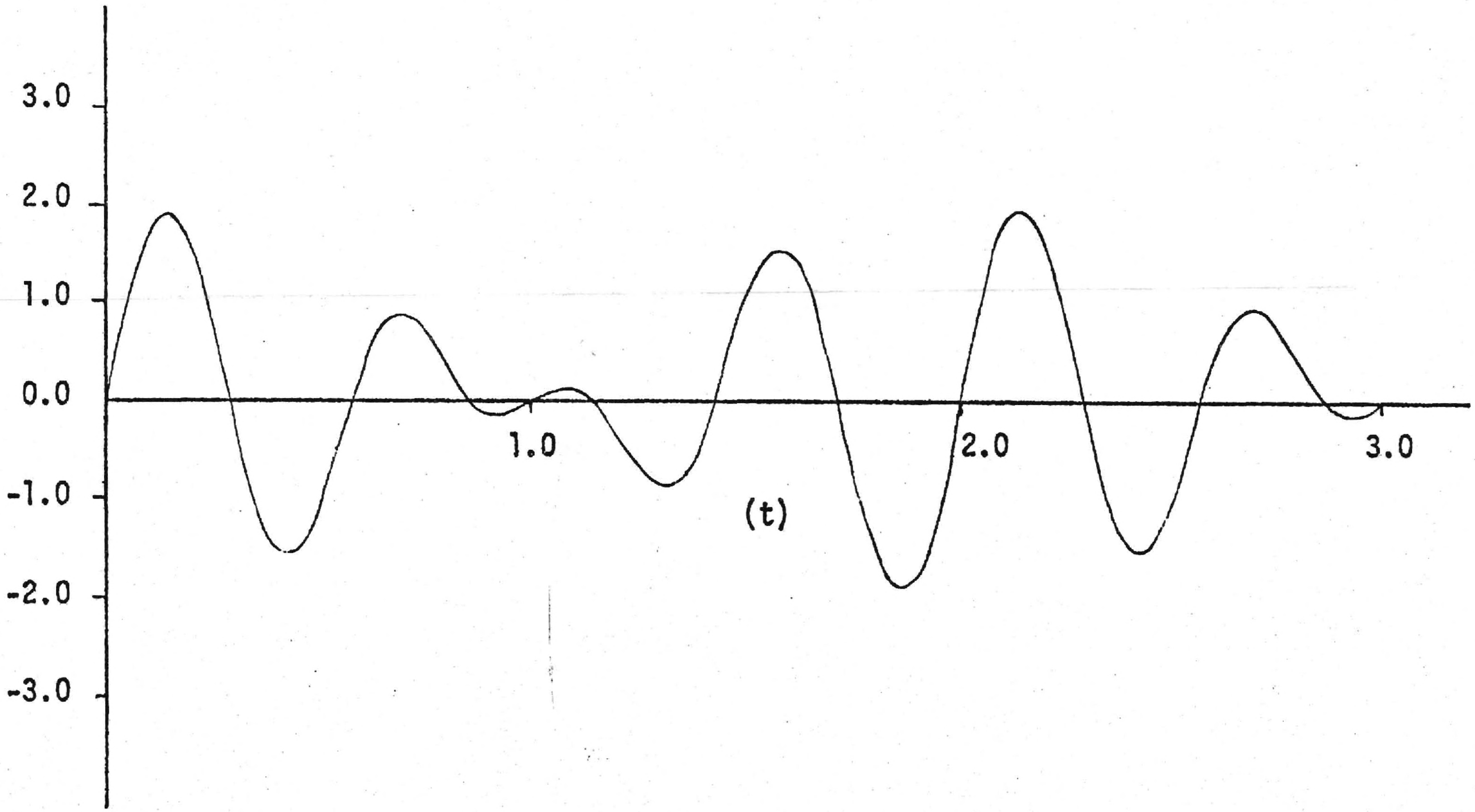


FIG 17

(17)

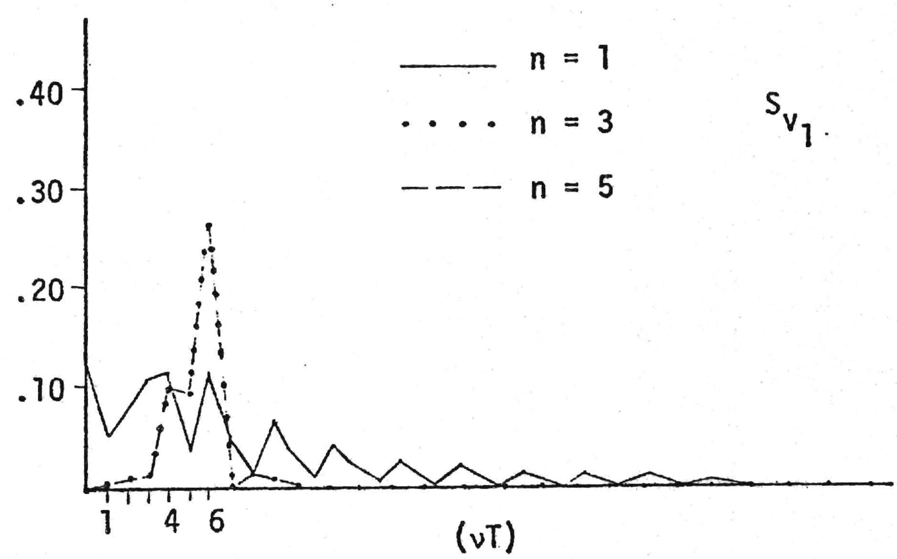


FIG 18

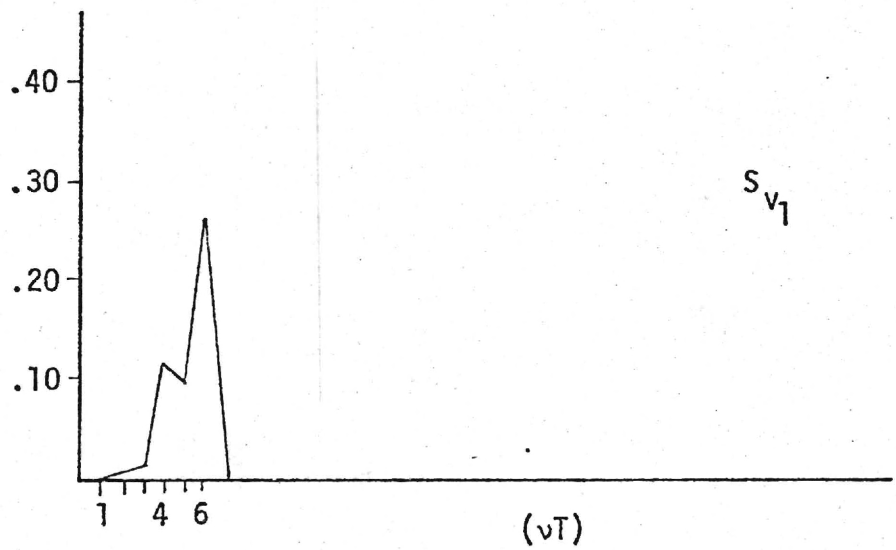


FIG 19

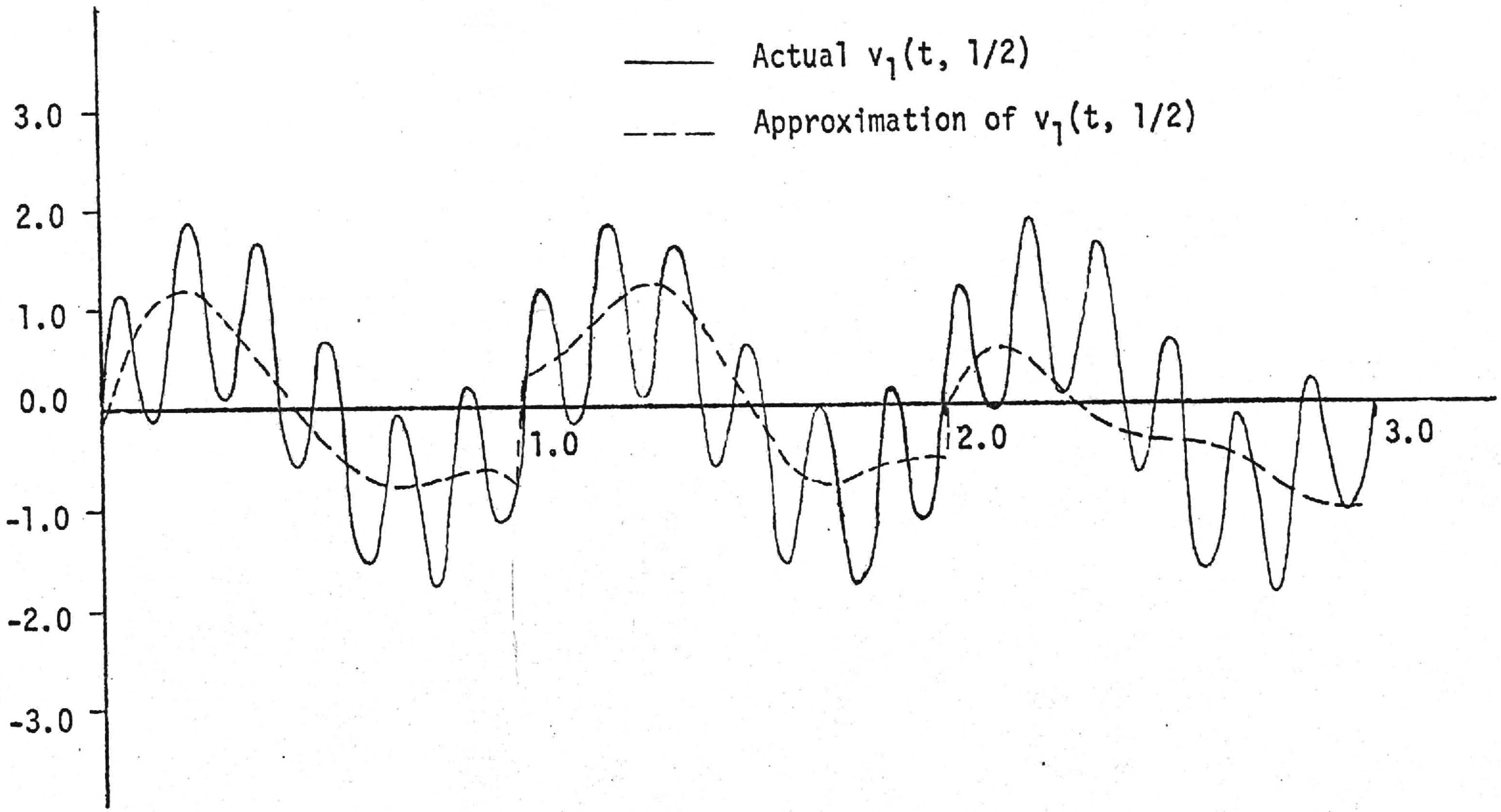

Actual $v_1(t, 1/2)$
Approximation of $v_1(t, 1/2)$
3.0
2.0
1.0
0.0
-1.0
-2.0
-3.0
1.0
2.0
3.0

FIG 20

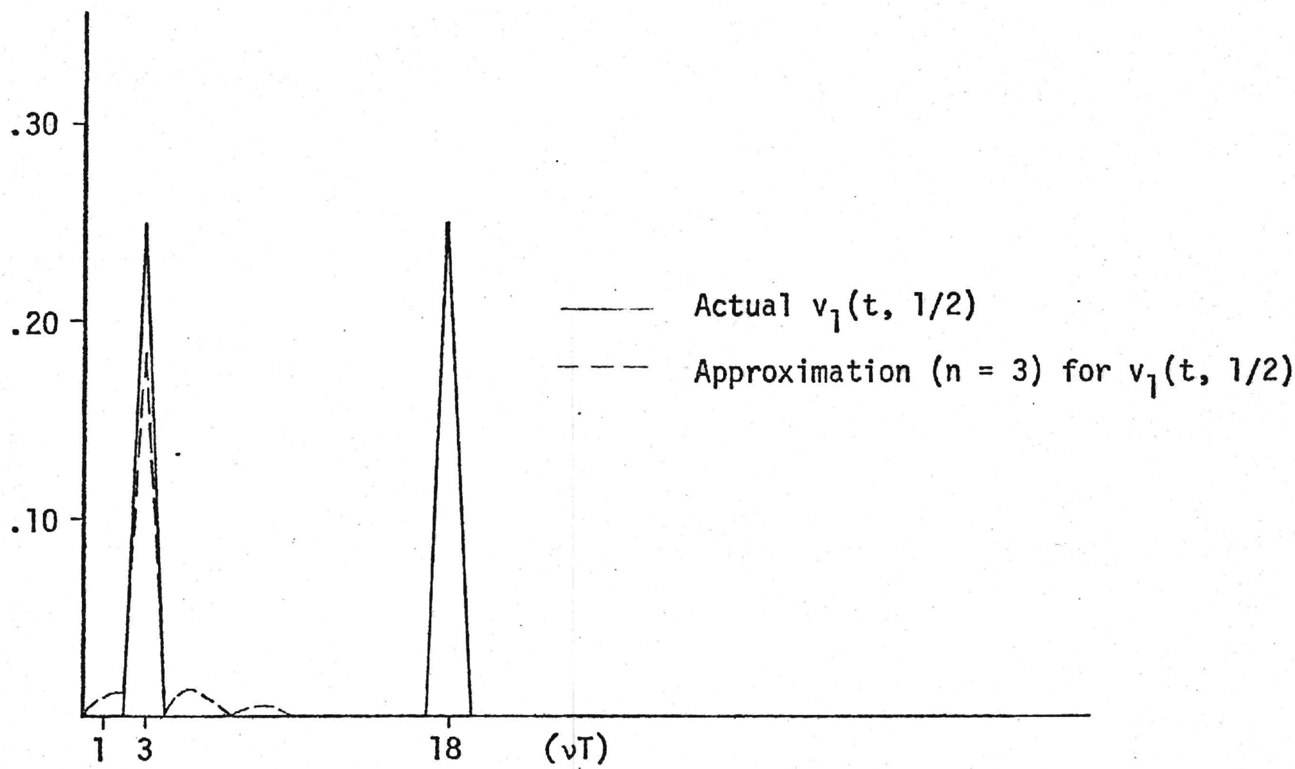


FIG 21

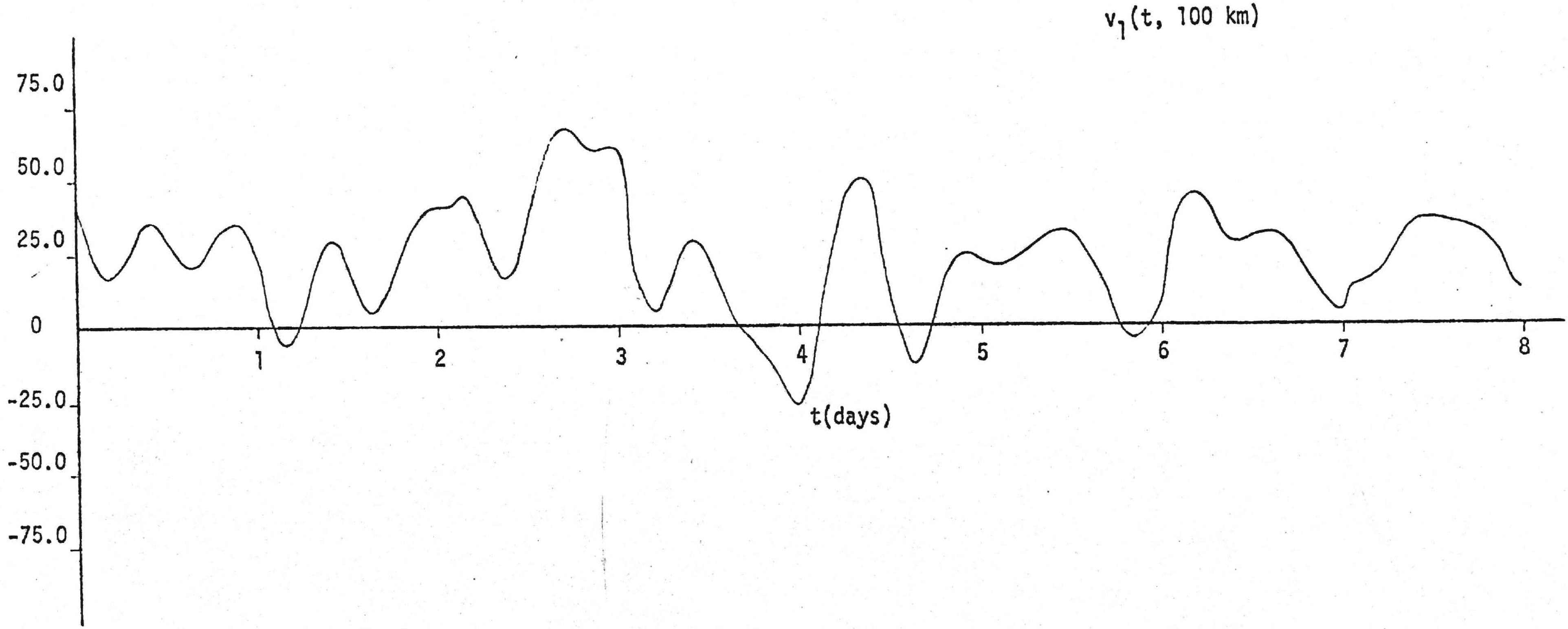
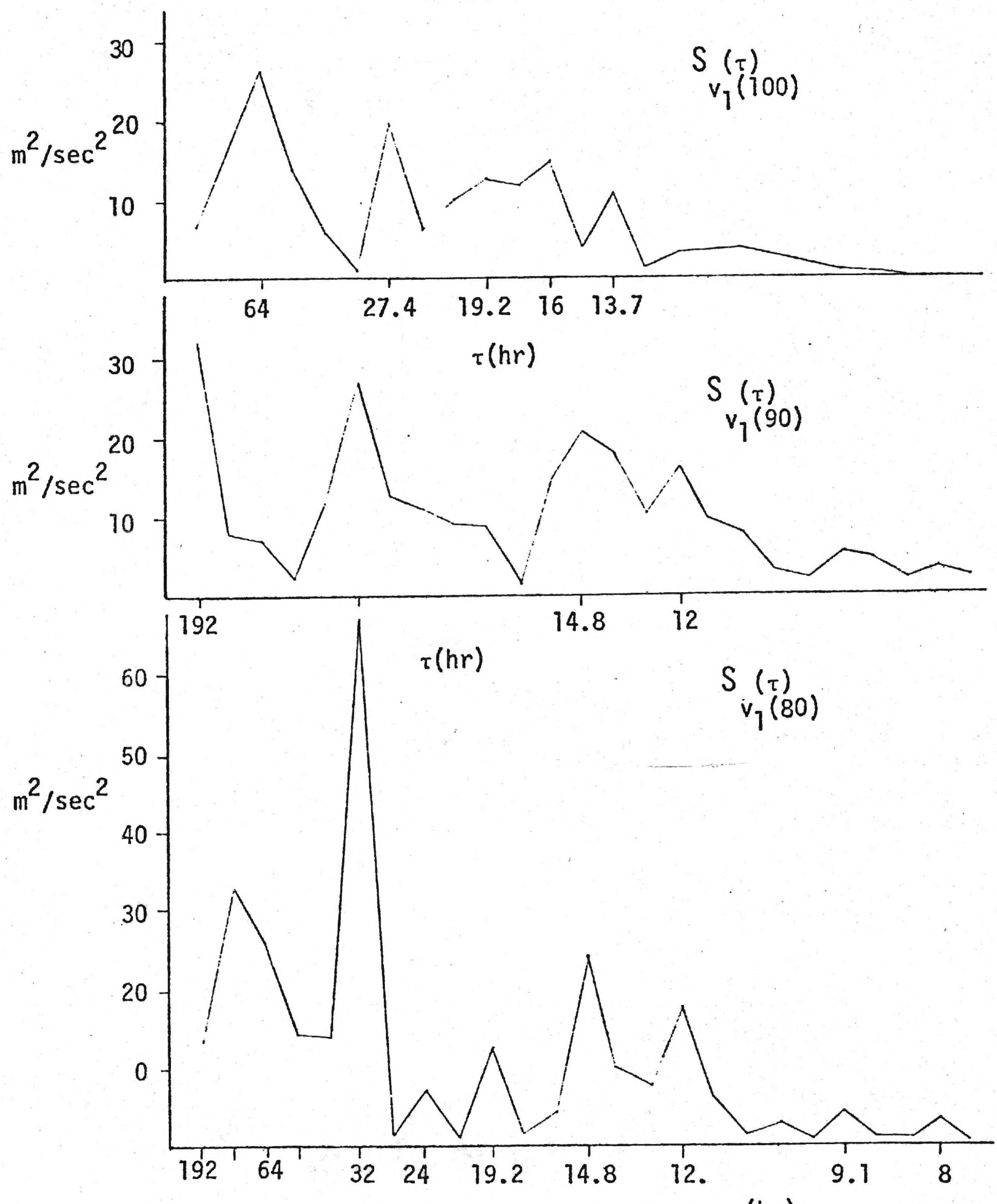
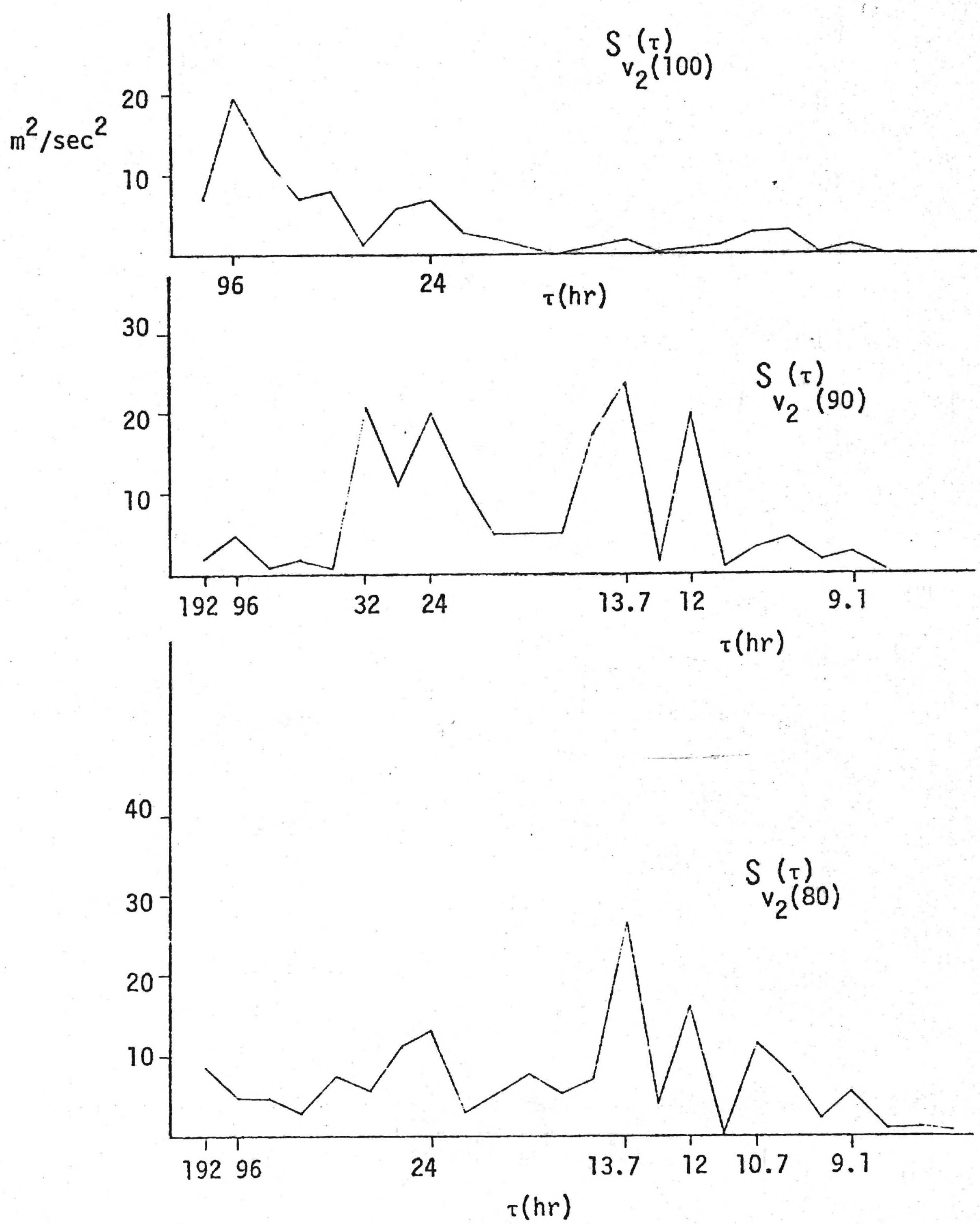


FIG 22



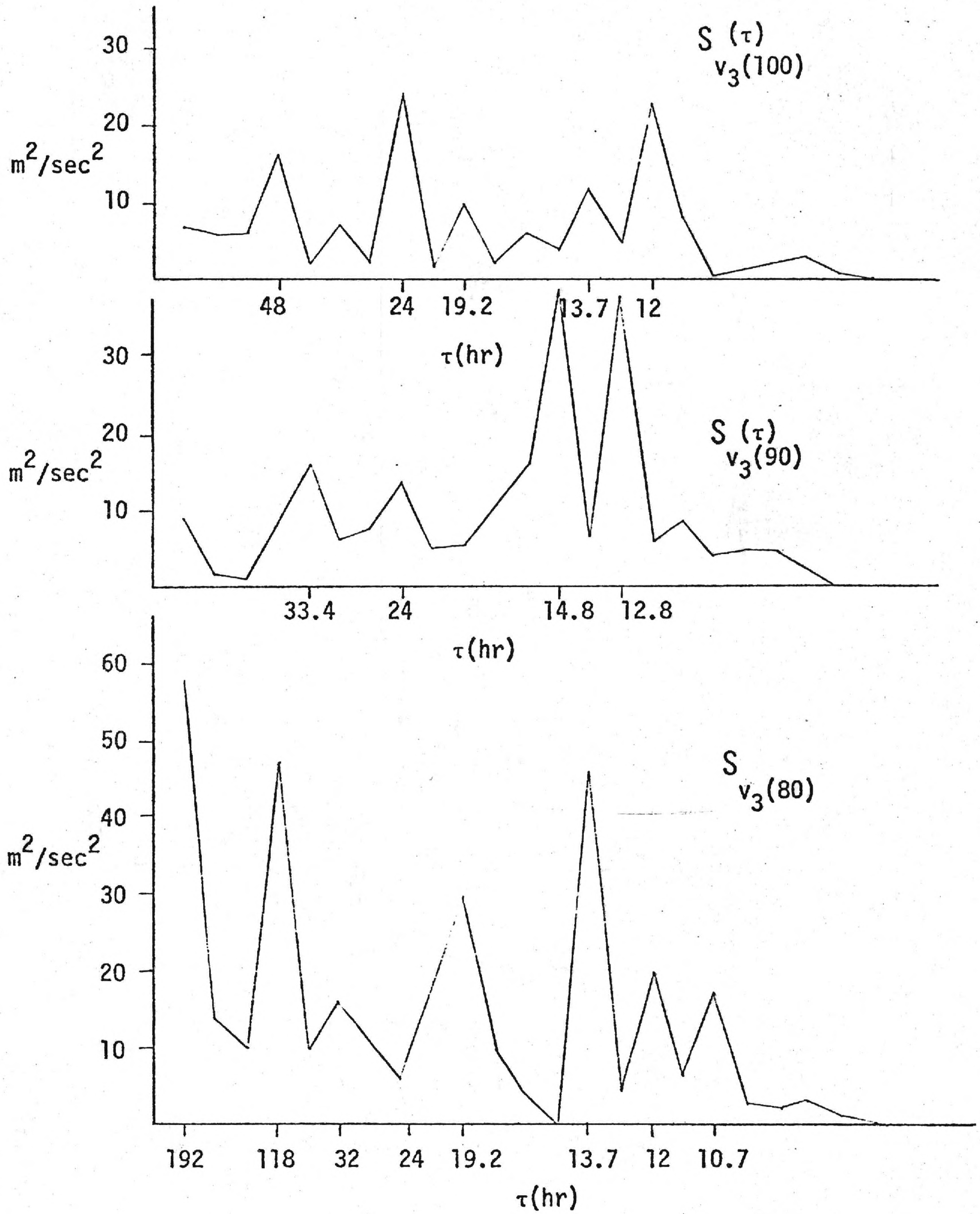
30
20
10
m^2/sec^2
$S_{v_1(100)}(\tau)$
64
27.4
19.2
16
13.7
τ(hr)
30
20
10
m^2/sec^2
$S_{v_1(90)}(\tau)$
192
14.8
12
τ(hr)
60
50
40
30
20
0
m^2/sec^2
$S_{v_1(80)}(\tau)$
192
64
32
24
19.2
14.8
12.
9.1
8
τ(hr)

FIG 23



$S_{v_2(100)}(\tau)$
m^2/sec^2
20
10
96
24
τ(hr)
$S_{v_2}(\tau)$ (90)
30
20
10
192 96
32 24
13.7 12
9.1
τ(hr)
40
$S_{v_2(80)}(\tau)$
30
20
10
192 96
24
13.7 12 10.7
9.1
τ(hr)

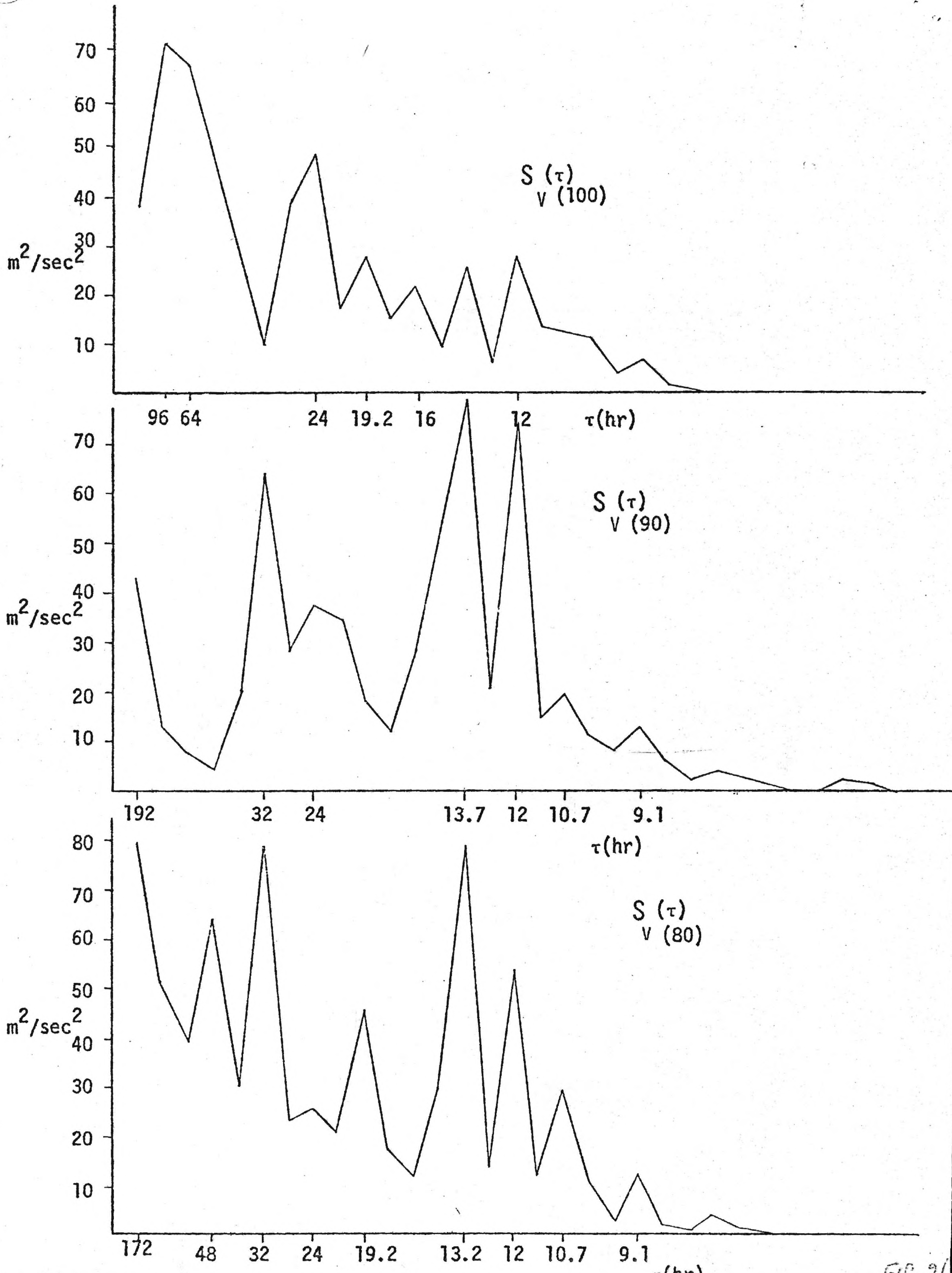
FIG 24



S (τ) v3(100)
30
20
10
m2/sec2
48
24
19.2
13.7
12
τ(hr)
S (τ) v3(90)
30
20
10
m2/sec2
33.4
24
14.8
12.8
τ(hr)
S v3(80)
60
50
40
30
20
10
m2/sec2
192
118
32
24
19.2
13.7
12
10.7
τ(hr)

FIG 25

26



70
60
50
40
30
20
10
m^2/sec^2
$S_V(\tau)$ (100)
96 64 24 19.2 16 12
τ(hr)
70
60
50
40
30
20
10
m^2/sec^2
$S_V(\tau)$ (90)
192 32 24 13.7 12 10.7 9.1
τ(hr)
80
70
60
50
40
30
20
10
m^2/sec^2
$S_V(\tau)$ (80)
172 48 32 24 19.2 13.2 12 10.7 9.1
τ(hr)

FIG 26

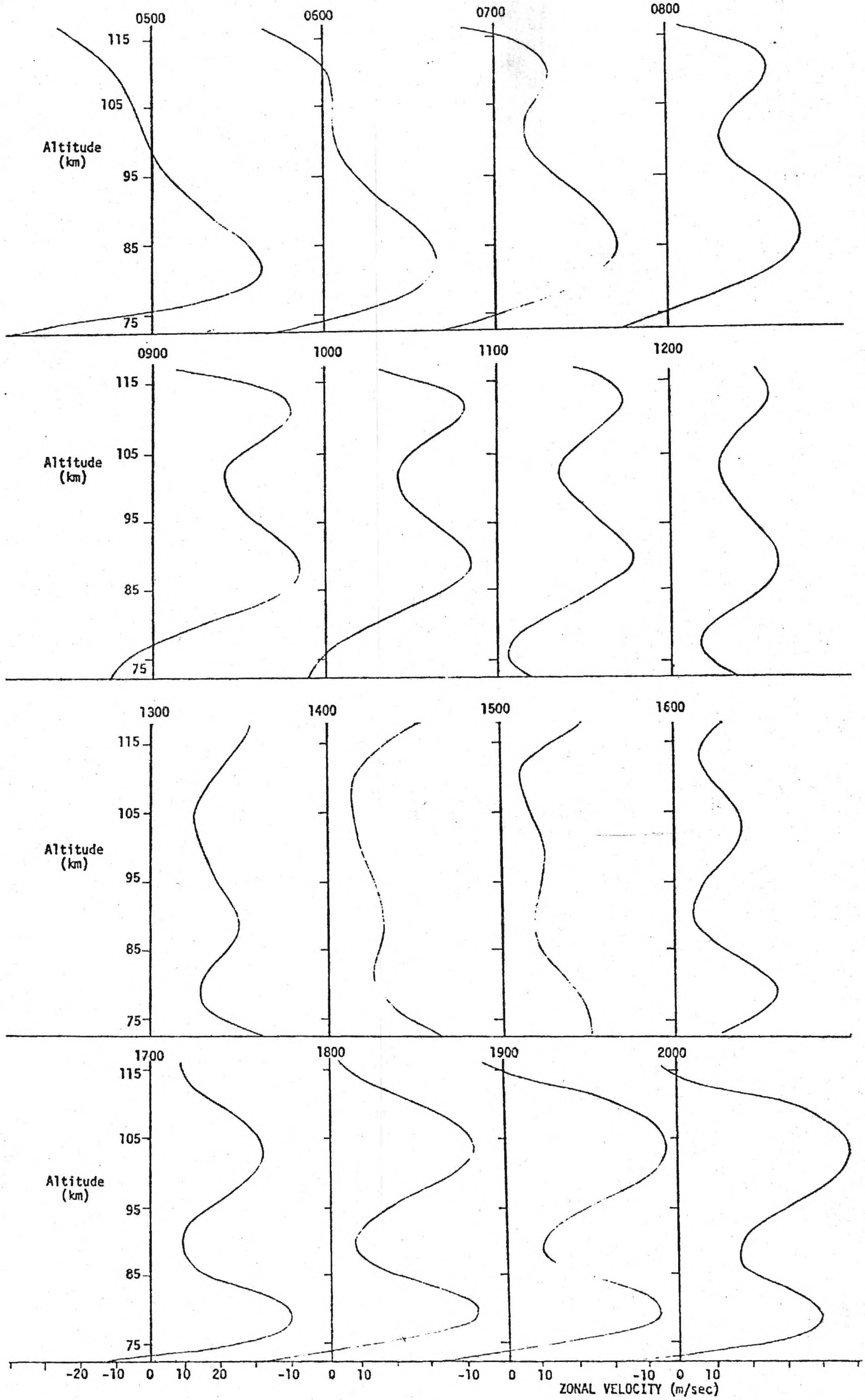

0500
0600
0700
0800
0900
1000
1100
1200
1300
1400
1500
1600
1700
1800
1900
2000
Altitude (km)
115
105
95
85
75
-20 -10 0 10 20
-10 0 10
-10 0 10
-10 0 10
ZONAL VELOCITY (m/sec)

FIG 27

Radio Meteor Winds Measured Over Atlanta (34° N, 84° W)

August, 1974 - December, 1976

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Interim Technical Report on research supported by the Atmospheric Research Section of the National Science Foundation, under Grant NO. ATM75-14414.

Georgia Tech Project No. E-16-668

Contract Period June 1, 1975 - May 31, 1977

Radio Meteor Winds Measured Over Atlanta (34° N, 84° W)

August, 1974 - December, 1976

CONTENTS

Radio Meteor Winds Measured Over Atlanta (34° N, 84° W)

August, 1974 - December, 1976

Introduction.

Since August, 1974, the Georgia Tech Radio Meteor Wind Facility has been in routine operation, measuring winds between 80 and 100 kilometers altitude over Atlanta, Georgia, U.S.A.

A continuous wave technique is employed, with a transmitter located on the Georgia Tech campus, and a receiving site at Technology Park/Atlanta, 27 km northeast of the campus. A description of the equipment has been published by Roper (1975a), and a detailed systems manual is available (Roper, 1975b).

Results.

The tabulations presented in this report are the result of matching the data against the model developed by Groves (1959). The model assumes cubic variations with height of the north-south and east-west components of the prevailing wind and the diurnal and semidiurnal wind components. The vertical wind is considered to be constant with height, but having diurnal and semidiurnal periodicities in time. Vertical winds are not tabulated; their significance is being further investiaged, but, in general, their amplitudes are less than 10% of the horizontal components.

Wind amplitudes are in meters sec^{-1}; wind directions are positive for a wind blowing toward the east (a westerly) and toward the north (a southerly). Phases of the diurnal and semidiurnal components are times of maximum amplitude relative to local mean solar midnight (local mean solar time for Atlanta is Coordinated Universal Time minus 5 hours and 37 minutes).

In the tables, HEIGHT is the altitude in kilometers; MEAN is the prevailing wind, the constant coefficient of the Fourier series fitted to the data over the interval of measurement; and ER is the error to be associated with each component, be it amplitude (meters sec^{-1}) or phase (hours), and is one standard deviation.

While every effort is made to operate the facility continuously, interference from aircraft reflections and inadequate manpower have proved to be a problem. Significant results have been achieved by averaging from 5 days to 2 weeks data - averaging intervals appear as headers to the wind printout, and there are some gaps.

Some uncertainties exist with regard to the 1976 data. Overall wind magnitudes and errors are higher than in 1975. This could possible be due to larger random wind components in 1976, but there is, as yet, no satisfactory explanation for this aspect of these results.

Time has not yet allowed a complete discussion of the results, but a preliminary overview of the results through February, 1976 is presented as an appendix.

Acknowledgements.

The Georgia Tech Radio Meteor Wind Facility was initially funded by the Georgia Institute of Technology. Since 1971, support has been provided by the Atmospheric Sciences Section of the National Science Foundation, first under Grant No. GA26626 (1971-1975), and currently under Grant No. ATM75-14414. Additional support for data analysis has been provided by the National Aeronautics and Space Administration under Grant No. NGL 11-002-004.

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Groves, G. V., "A Theory for Determining Upper Atmosphere Winds from Radio Observations on Meteor Trails", J. Atmos. Terrest. Phys., 16, 344-356, 1959.

Roper, R. G., "The Measurement of Meteor Winds Over Atlanta (34° N, 84° W)°", Radio Sci., 10, 363-369, 1975a.

Roper, R. G., "The Georgia Tech Radio Meteor Wind Facility", Final Technical Report on research supported by the Atmospheric Sciences Section of the National Science Foundation under Grant No. GA26626, May, 1975b.

METEOR WINDS OVER ATLANTA (34° N, 84° W)
FOR THE PERIOD AUGUST 9, 1974 TO AUGUST 17, 1974

EAST-WEST COMPONENTS

			24 Hour Component				12 Hour Component			
HEIGHT	MEAN	ER	AMP	ER	PHASE	ER	AMP	ER	PHASE	ER
100	9	8	5	11	6.6	8	22	11	11.8	1
96	-9	7	16	10	13.8	2	21	10	10.9	1
92	-16	6	23	8	14.8	1	9	8	10.4	2
88	-15	6	24	9	15.3	1	6	8	4.7	3
84	-12	7	21	10	15.1	2	12	9	4.1	1
80	-9	11	21	15	13.0	3	10	18	0.5	3

NORTH-SOUTH COMPONENTS

100	-13	7	3	9	12.9	10	25	10	5.0	1
96	-14	6	7	9	14.2	5	28	9	5.3	1
92	-12	5	5	7	5.8	5	24	7	5.0	1
88	-6	5	18	7	4.4	1	18	7	4.3	1
84	0	6	22	9	4.6	1	11	8	2.7	2
80	8	9	8	13	8.5	6	14	14	11.9	2

METEOR WINDS OVER ATLANTA (34° N, 84° W)
FOR THE PERIOD AUGUST 17, 1974 TO AUGUST 31, 1974

EAST-WEST COMPONENTS

			24 Hour Component				12 Hour Component			
HEIGHT	MEAN	ER	AMP	ER	PHASE	ER	AMP	ER	PHASE	ER
100	32	10	54	18	11	1	25	14	11.6	1
96	23	11	54	20	11.3	1	11	14	10.0	2
92	5	9	25	16	11.5	1	11	10	7.0	2
90	- 5	8	8	13	11.9	4	15	11	6.3	1
88	-12	8	8	13	23.0	4	17	11	5.9	1
84	-17	8	21	13	23.3	2	14	11	5.6	1
80	1	13	8	23	12.0	6	7	16	10.4	5

NORTH-SOUTH COMPONENTS

100	-27	11	20	18	0.6	2	29	14	5.0	1
96	-30	11	36	19	23.3	1	29	14	5.1	1
92	-25	9	36	16	23.4	1	28	12	5.3	1
88	-15	8	26	14	.2	1	24	12	5.6	1
84	- 3	8	15	10	3.2	3	17	11	6.5	1
80	9	11	21	12	7.1	3	18	13	8.8	2

METEOR WINDS OVER ATLANTA (34° N, 84° W)
FOR THE PERIOD AUGUST 31, 1974 TO SEPTEMBER 14, 1974

EAST-WEST COMPONENTS

			24 Hour Component				12 Hour Component			
HEIGHT	MEAN	ER	AMP	ER	PHASE	ER	AMP	ER	PHASE	ER
100	18	7	16	8	17.5	3	13	9	3.4	1
96	13	6	26	8	15.5	1	2	8	5.6	8
92	14	5	21	7	14.7	1	9	7	9.9	2
88	17	6	11	9	12.7	3	17	8	10.4	1
84	16	7	9	10	8.9	4	18	9	10.6	1
80	9	10	12	14	10.5	4	10	12	10.5	3

NORTH-SOUTH COMPONENTS

100	- 6	5	20	7	4.7	2	8	7.1	8.0	2
96	- 7	5	16	6	3.8	2	10	7	8.9	1
92	- 7	4	9	5	4.2	3	8	6	8.1	1
88	- 5	4	5	6	8.7	5	7	7	6.4	2
84	- 1	5	8	7	9.5	3	7	7	4.9	2
80	5	8	13	9	5.7	4	8	11	1.5	2

METEOR WINDS OVER ATLANTA (34° N, 84° W)
FOR THE PERIOD SEPTEMBER 14, 1974 TO OCTOBER 17, 1974

EAST-WEST COMPONENTS

			24 Hour Component				12 Hour Component			
HEIGHT	MEAN	ER	AMP	ER	PHASE	ER	AMP	ER	PHASE	ER
100	6	7	34	10	22.0	1	14	10	2.4	1
96	5	7	40	10	22.3	1	23	9	.4	1
92	0	6	28	8	22.1	1	28	8	11.9	0
88	- 5	6	8	8	20.3	5	23	9	11.6	1
84	-10	7	14	12	11.8	2	10	10	11.3	2
80	-12	9	21	15	10.6	2	12	14	5.2	2

NORTH-SOUTH COMPONENTS

100	- 9	6	3	9	22.5	10	17	8	6.5	1
96	-10	6	2	7	20.0	16	15	8	7.4	1
92	- 7	5	2	6	21.2	13	5	7	7.1	2
88	- 0	5	3	7	23.8	8	8	7	2.6	2
84	6	6	4	9	1.2	6	15	8	2.4	1
80	9	7	4	10	2.5	8	8	9	2.4	2

METEOR WINDS OVER ATLANTA (34° N, 84° W)
FOR THE PERIOD OCTOBER 17, 1974 TO OCTOBER 26, 1974

EAST-WEST COMPONENTS

			24 Hour Component				12 Hour Component			
HEIGHT	MEAN	ER	AMP	ER	PHASE	ER	AMP	ER	PHASE	ER
100	1	10	3	14	3.7	17	28	12	2.9	1
96	- 2	8	8	13	3.2	6	38	11	2.4	1
92	- 7	7	6	10	4.3	8	27	10	1.6	1
88	-10	8	4	10	7.2	10	19	11	11.8	1
84	-10	9	6	11	7.7	9	20	12	10.9	1
80	- 3	10	17	13	4.2	4	6	15	10.6	5

NORTH-SOUTH COMPONENTS

100	- 1	7	6	11	13.3	6	18	10	2.5	1
96	- 3	7	6	10	22.8	6	18	9	1.9	1
92	- 7	6	6	10	1.2	5	11	10	1.2	1
88	-11	7	6	10	5.0	7	7	10	11.0	3
84	-11	8	6	11	8.6	7	10	11	9.5	2
80	- 4	9	7	12	14.1	7	7	12	9.1	3

METEOR WINDS OVER ATLANTA (34° N, 84° W)
FOR THE PERIOD OCTOBER 26, 1974 TO NOVEMBER 19, 1974

EAST-WEST COMPONENTS

			24 Hour Component				12 Hour Component			
HEIGHT	MEAN	ER	AMP	ER	PHASE	ER	AMP	ER	PHASE	ER
100	-10	9	15	11	5.1	3	40	12	2.8	1
96	- 5	7	7	10	9	5	36	10	3.1	1
92	- 9	6	8	10	1.4	4	19	9	3.5	1
88	-16	7	11	10	4.2	3	5	9	6.2	4
84	-18	8	16	10	5.3	3	12	11	8.4	2
80	-11	9	14	15	5.3	3	6	16	7.6	4

NORTH-SOUTH COMPONENTS

100	- 8	7	14	9	8.7	3	22	10	4.5	1
96	- 4	6	16	9	10.9	2	26	8	5.2	1
92	1	5	14	7	9.8	2	22	7	5.2	1
88	5	6	14	7	7.2	2	12	8	4.9	1
84	7	6	14	8	5.7	3	3	9	4.4	5
80	6	8	2	11	6.6	19	7	13	8.4	3

METEOR WINDS OVER ATLANTA (34° N, 84° W)
FOR THE PERIOD NOVEMBER 19, 1974 TO NOVEMBER 28, 1974

EAST-WEST COMPONENTS

			24 Hour Component				12 Hour Component			
HEIGHT	MEAN	ER	AMP	ER	PHASE	ER	AMP	ER	PHASE	ER
100	-25	8	30	11	9.3	2	39	12	2.3	1
96	-33	7	15	9	8.3	3	47	11	2.3	0
92	-29	5	16	8	3.4	2	42	8	2.2	0
88	-18	6	27	9	2.0	1	31	9	1.9	0
84	- 9	7	25	11	1.6	1	20	10	1.6	1
80	- 9	9	3	16	15.9	14	14	13	1.3	2

NORTH-SOUTH COMPONENTS

100	- 3	7	4	10	4.2	11	4	11	3.5	5
96	- 2	7	8	9	6.4	5	6	10	9.9	3
92	6	5	12	8	1.1	2	14	8	10.5	1
88	15	5	25	8	23.5	1	19	7	10.9	1
84	21	6	28	10	23.4	1	17	9	11.1	1
80	17	8	10	11	3.1	4	5	11	10.4	5

METEOR WINDS OVER ATLANTA (34° N, 84° W)
FOR THE PERIOD NOVEMBER 28, 1974 TO DECEMBER 12, 1974

EAST-WEST COMPONENTS

			24 Hour Component				12 Hour Component			
HEIGHT	MEAN	ER	AMP	ER	PHASE	ER	AMP	ER	PHASE	ER
100	- 6	8	24	12	3.7	2	16	12	10.5	1
96	- 4	8	21	12	2.5	2	10	10	11.6	2
92	- 2	6	20	10	.7	1	7	9	2.3	2
88	- 1	6	19	10	23.2	2	13	8	3.7	1
84	- 6	7	13	11	22.4	3	12	9	4.2	2
80	-20	8	6	11	9.1	8	5	12	9.4	4

NORTH-SOUTH COMPONENTS

100	10	7	11	9	7.8	4	4	10	10.1	4
96	7	6	11	8	8.4	3	15	8	2.7	1
92	7	6	7	7	5.9	5	21	7	3.0	1
88	7	6	11	8	1.8	3	17	8	3.5	1
84	3	6	16	9	1.4	2	8	9	5.1	2
80	- 7	8	13	12	3.6	3	18	11	8	1

METEOR WINDS OVER ATLANTA (34° N, 84° W)
FOR THE PERIOD DECEMBER 12, 1974 TO DECEMBER 16, 1974

EAST-WEST COMPONENTS

HEIGHT	MEAN	ER	AMP	ER	PHASE	ER	AMP	ER	PHASE	ER
100	- 7	9	20	10	7.9	3	25	11	4.7	1
96	- 9	8	18	9	6.8	2	12	10	5.8	2
92	-10	7	18	10	5.2	2	7	8	5.4	3
88	-11	7	18	11	3.9	2	10	10	3.6	2
84	-13	7	15	12	3.2	2	14	11	3.1	1
80	-16	11	3	14	4.3	19	6	15	2.6	5

NORTH-SOUTH COMPONENTS

100	- 7	9	15	11	18.3	4	22	13	6.3	1
96	2	8	16	10	18.6	3	26	11	6.0	1
92	9	6	10	8	18.4	4	19	9	5.2	1
88	14	6	2	9	22.7	18	14	8	3.5	1
84	14	7	13	11	3.3	3	16	10	2.3	1
80	7	11	32	16	2.4	2	5	14	2.5	6

METEOR WINDS OVER ATLANTA (34° N, 84° W)
FOR THE PERIOD DECEMBER 16, 1974 TO DECEMBER 23, 1974

EAST-WEST COMPONENTS

			24 Hour Component				12 Hour Component			
HEIGHT	MEAN	ER	AMP	ER	PHASE	ER	AMP	ER	PHASE	ER
100	7	8	18	12	5.8	3	27	12	2.6	1
96	10	7	23	12	2.2	1	24	11	1.8	1
92	1	6	24	10	2.7	1	9	9	2.3	2
88	-10	6	22	10	4.3	1	13	9	6.5	1
84	-18	7	17	10	5.9	3	23	11	6.9	1
80	-15	9	1	11	6.7	89	7	15	8	3

NORTH-SOUTH COMPONENTS

100	4	7	14	11	14.7	3	15	10	8.7	1
96	15	7	12	9	19.9	3	13	9	10.1	1
92	18	6	15	9	22.6	2	7	8	11	2
88	16	5	18	9	.6	1	5	7	3.4	3
84	12	6	21	10	1.4	1	13	8	4.2	1
80	11	8	23	13	.7	2	15	10	4.3	2

METEOR WINDS OVER ATLANTA (34° N, 84° W)
FOR THE PERIOD DECEMBER 23, 1974 TO DECEMBER 27, 1974

EAST-WEST COMPONENTS

			24 Hour Component				12 Hour Component			
HEIGHT	MEAN	ER	AMP	ER	PHASE	ER	AMP	ER	PHASE	ER
100	3	9	30	11	7.2	2	26	12	4.2	1
96	- 3	8	22	10	6.2	2	21	10	4.9	1
92	- 7	6	14	10	3.9	2	15	8	5.9	1
88	-10	7	16	12	.9	2	10	11	7.2	2
84	- 8	8	20	13	.5	2	6	13	8.2	3
80	- 1	11	23	17	2.3	2	6	15	3.2	5

NORTH-SOUTH COMPONENTS

100	18	8	3	10	5.5	15	13	11	9.1	2
96	16	7	1	10	1.0	33	4	10	10.9	5
92	16	6	7	9	2.1	5	4	9	2.0	4
88	17	7	12	11	2.6	3	6	10	2.9	3
84	16	8	9	12	3.1	4	7	11	3.0	3
80	12	11	9	19	13.8	5	9	17	2.4	3

METEOR WINDS OVER ATLANTA (34° N, 84° W)
FOR THE PERIOD DECEMBER 27, 1974 TO DECEMBER 31, 1974

EAST-WEST COMPONENTS

			24 Hour Component				12 Hour Component			
HEIGHT	MEAN	ER	AMP	ER	PHASE	ER	AMP	ER	PHASE	ER
100	13	11	10	17	8.3	7	4	16	8.7	8
96	9	8	20	12	3.6	2	8	12	10.2	3
92	9	8	29	11	2.4	1	9	11	9.9	2
88	10	8	32	12	1.6	1	7	11	9.1	3
84	9	9	28	14	.8	2	3	15	7.4	6
80	2	11	17	16	23.4	3	7	17	3.3	5

NORTH-SOUTH COMPONENTS

100	7	9	17	12	5.6	3	13	13	2.8	2
96	4	9	12	13	3.1	4	25	13	3.9	1
92	4	7	10	10	23.6	4	23	11	3.8	1
88	5	8	12	11	21.0	4	14	10	3.1	2
84	10	9	13	13	20.0	4	8	13	1.1	3
80	18	9	8	13	21.0	7	5	13	10.9	5

METEOR WINDS OVER ATLANTA (34° N, 84° W)
FOR THE PERIOD JANUARY 1, 1975 TO JANUARY 14, 1975

EAST-WEST COMPONENTS

			24 Hour Component				12 Hour Component			
height	mean	er	amp	er	phase	er	amp	er	phase	er
100	3	10	12	13	16.4	5	4	12	11.4	6
96	1	8	5	11	15.6	7	7	10	11.4	3
92	- 6	6	3	8	19.1	13	7	8	.1	2
88	-12	6	5	8	22.4	6	9	8	1.3	2
84	-15	7	7	10	23.3	5	16	10	1.7	1
80	-11	9	6	14	2.1	7	26	12	1.5	1

NORTH-SOUTH COMPONENTS

100	3	8	24	14	2.4	1	16	13	8.0	1
96	- 2	7	18	11	1.2	2	14	11	8.7	1
92	- 2	6	12	8	23.4	2	11	9	8.8	1
88	1	6	10	8	20.7	4	5	9	8.5	3
84	5	7	9	9	19.3	5	2	10	4.3	9
80	8	8	6	10	21.7	8	9	12	2.7	2

METEOR WINDS OVER ATLANTA (34° N, 84° W)
FOR THE PERIOD JANUARY 10, 1975 TO JANUARY 22, 1975

EAST-WEST COMPONENTS

			24 Hour Component				12 Hour Component			
HEIGHT	MEAN	ER	AMP	ER	PHASE	ER	AMP	ER	PHASE	ER
100	-26	13	42	22	14.5	1	32	18	6.1	1
96	-24	11	38	17	15.1	1	31	16	6.6	1
92	-17	8	18	10	18.0	3	13	11	6.0	2
88	-10	8	27	12	23.2	2	15	13	1.9	1
84	- 6	10	36	15	.2	1	29	16	1.3	1
80	- 7	11	11	16	22.9	6	20	15	.3	2

NORTH-SOUTH COMPONENTS

100	1	9	14	14	23.9	3	18	12	6.3	1
96	6	7	18	11	1.0	2	21	10	5.8	1
92	6	6	17	9	2.8	2	16	9	6.6	1
88	5	7	18	10	5.0	2	16	10	8.2	1
84	7	8	21	11	5.8	2	15	11	9.2	2
80	13	10	23	12	4.7	3	7	14	1.4	4

METEOR WINDS OVER ATLANTA (34° N, 84° W)
FOR THE PERIOD JANUARY 22, 1975 TO JANUARY 31, 1975

EAST-WEST COMPONENTS

			24 Hour Component				12 Hour Component			
HEIGHT	MEAN	ER	AMP	ER	PHASE	ER	AMP	ER	PHASE	ER
100	25	13	2	14	7.8	52	43	21	1.9	1
96	15	11	20	15	4.8	3	34	16	1.9	1
92	2	9	19	11	5.6	3	9	12	.3	2
88	- 9	8	12	11	7.9	4	26	12	8.9	1
84	-14	10	10	15	10.7	5	37	14	8.5	1
80	- 9	15	8	17	6.7	11	17	17	7.0	2

NORTH-SOUTH COMPONENTS

100	-15	11	28	13	19.5	3	18	18	3.1	2
96	- 4	9	25	13	18.9	2	26	15	2.5	1
92	2	7	15	11	20.8	3	19	11	3.3	1
88	3	7	16	10	1.2	2	18	9	4.9	1
84	2	8	22	11	2.7	2	21	11	5.0	1
80	1	11	10	14	3.5	6	35	14	2.9	1

METEOR WINDS OVER ATLANTA (34° N, 84° W)
FOR THE PERIOD JANUARY 31, 1975 TO FEBRUARY 7, 1975

EAST-WEST COMPONENTS

			24 Hour Component				12 Hour Component			
HEIGHT	MEAN	ER	AMP	ER	PHASE	ER	AMP	ER	PHASE	ER
100	23	10	18	16	15.1	2	13	14	1.8	2
96	18	9	2	12	15.1	19	21	12	1.6	1
92	16	7	15	10	3.3	2	17	10	2.0	1
88	15	7	28	11	3.2	1	9	10	3.2	2
84	13	8	31	13	2.9	1	7	11	5.2	3
80	8	9	19	14	1.5	2	1	12	5.8	26

NORTH-SOUTH COMPONENTS

100	5	7	7	11	14.0	5	7	11	2.5	3
96	5	7	8	9	.2	5	3	10	2.2	5
92	5	6	9	8	23.6	3	2	8	10.5	10
88	4	5	5	8	20.9	6	3	7	9.6	6
84	4	6	5	9	15.2	7	1	8	2.4	12
80	4	7	5	10	9.3	8	13	11	3.1	1

METEOR WINDS OVER ATLANTA (34° N, 84° W)
FOR THE PERIOD FEBRUARY 7, 1975 TO FEBRUARY 16, 1975

EAST-WEST COMPONENTS

			24 Hour Component				12 Hour Component			
HEIGHT	MEAN	ER	AMP	ER	PHASE	ER	AMP	ER	PHASE	ER
100	31	10	4	13	19.4	15	18	15	2.3	1
96	27	9	6	13	16.7	8	24	13	1.4	1
92	14	7	14	11	14.6	2	23	10	1.1	1
88	0	9	24	14	14.1	2	18	12	.9	1
84	-10	11	28	18	14.0	2	11	14	.1	3
80	-10	12	21	18	14.5	3	15	15	10.4	2

NORTH-SOUTH COMPONENTS

100	6	9	10	14	16.8	5	27	13	8.9	1
96	10	7	5	10	19.8	7	23	10	8.6	1
92	8	6	7	9	4.6	4	18	9	7.7	1
88	4	6	17	9	6.3	2	15	8	6.4	1
84	- 0	7	20	9	7.5	2	14	9	5.1	1
80	- 2	8	16	9	10.6	3	11	10	3.1	2

METEOR WINDS OVER ATLANTA (34° N, 84° W)
FOR THE PERIOD FEBRUARY 16, 1975 TO FEBRUARY 28, 1975

EAST-WEST COMPONENTS

			24 Hour Component				12 Hour Component			
HEIGHT	MEAN	ER	AMP	ER	PHASE	ER	AMP	ER	PHASE	ER
100	19	9	25	11	9.0	2	24	13	1.2	1
96	19	7	10	11	11.6	4	11	10	.5	2
92	14	6	13	10	13.6	2	9	9	7.7	2
88	7	7	15	12	13.2	2	25	12	6.9	1
84	2	9	10	14	12.3	4	30	12	6.4	1
80	3	12	10	21	1.2	5	23	15	5.0	1

NORTH-SOUTH COMPONENTS

100	- 2	7	7	10	1.7	5	22	9	6.6	1
96	- 4	6	6	10	2.2	5	17	9	6.6	1
92	- 1	6	8	9	2.5	3	9	8	6.4	2
88	6	6	11	9	2.6	3	2	8	2.9	8
84	14	6	15	9	2.6	2	10	9	1.3	2
80	22	9	20	14	2.7	2	18	12	1.4	1

METEOR WINDS OVER ATLANTA (34° N, 84° W)
FOR THE PERIOD FEBRUARY 28. 1975 TO MARCH 9, 1975

EAST-WEST COMPONENT

			24 Hour Component				12 Hour Component			
HEIGHT	MEAN	ER	AMP	ER	PHASE	ER	AMP	ER	PHASE	ER
100	22	9	9	14	3.9	5	28	13	1.9	1
96	24	7	7	11	1.3	5	19	11	2.0	1
92	19	5	3	8	.8	9	4	8	1.5	3
88	12	6	3	8	5.7	12	9	9	8.9	2
84	8	7	10	11	3.7	3	12	10	9.5	2
80	12	10	32	17	2.3	1	18	15	.4	1

NORTH-SOUTH COMPONENTS

100	- 1	7	4	9	18.5	11	8	11	7.7	2
96	- 1	6	5	7	21.5	7	10	8	8.5	2
92	- 1	5	4	7	1.8	5	7	7	8.1	2
88	- 2	5	7	8	5.0	4	4	8	6.2	3
84	- 5	6	7	8	6.2	5	3	8	4.4	6
80	-11	8	2	11	15.4	26	7	11	11.0	3

METEOR WINDS OVER ATLANTA (34° N, 84° W)
FOR THE PERIOD MARCH 9, 1975 TO MARCH 16, 1975

EAST-WEST COMPONENTS

			24 Hour Component				12 Hour Component			
HEIGHT	MEAN	ER	AMP	ER	PHASE	ER	AMP	ER	PHASE	ER
100	21	12	22	19	1.8	2	1	16	2.6	31
96	36	9	33	15	2.2	1	19	12	3.9	1
92	30	7	20	11	3.8	2	17	9	4.8	1
88	17	8	16	10	9	3	15	12	6.7	1
84	7	9	25	15	11.5	2	17	14	8.2	1
80	13	13	7	21	11.4	9	11	15	10.7	4

NORTH-SOUTH COMPONENTS

100	- 2	9	14	13	22.9	3	13	11	3.3	2
96	-11	7	8	10	22.6	5	9	11	6.5	2
92	- 9	6	5	9	1.9	6	8	9	6.7	2
88	- 4	6	9	8	5.3	4	5	8	4.4	4
84	- 1	7	14	9	6.3	3	10	10	2.8	2
80	- 8	9	16	12	7.4	4	8	14	2.6	3

METEOR WINDS OVER ATLANTA (34° N, 84° W)
FOR THE PERIOD MARCH 16, 1975 TO MARCH 27, 1975

EAST-WEST COMPONENTS

			24 Hour Component				12 Hour Component			
HEIGHT	MEAN	ER	AMP	ER	PHASE	ER	AMP	ER	PHASE	ER
100	11	12	48	19	1.1	1	4	17	4.4	8
96	26	11	32	16	2.3	1	17	14	1.1	2
92	21	9	5	14	3.2	8	19	13	.9	1
88	8	9	22	14	15.0	2	13	13	.4	2
84	- 3	10	36	16	15.2	1	12	14	10.7	2
80	- 0	15	23	24	15.3	3	25	18	10.0	2

NORTH-SOUTH COMPONENTS

100	0	13	30	21	1.7	2	14	18	11.9	3
96	13	11	8	17	.8	6	16	15	.6	2
88	- 5	8	12	13	3.2	4	15	11	3.4	2
84	-16	9	23	14	3.1	2	21	14	5.2	1
80	-12	14	29	18	2.9	3	38	20	6.5	1

METEOR WINDS OVER ATLANTA (34° N, 84° W)
FOR THE PERIOD MAY 14, 1975 TO MAY 19, 1975

EAST-WEST COMPONENTS

			24 Hour Component				12 Hour Component			
HEIGHT	MEAN	ER	AMP	ER	PHASE	ER	AMP	ER	PHASE	ER
100	11	9	9	11	5.6	6	15	13	11.9	1
96	2	7	13	10	8.8	3	11	10	2.0	2
92	3	6	12	9	10.0	3	19	10	1.7	1
88	8	7	9	10	11.2	4	28	11	1.1	1
84	11	7	9	11	12.0	4	34	12	.8	1
80	5	9	16	15	11.1	3	26	15	.7	1

NORTH-SOUTH COMPONENTS

100	-19	7	8	11	10.8	5	15	10	6.2	1
96	- 9	6	22	9	10.2	2	8	8	3.0	2
92	7	5	25	7	8.9	1	14	8	2.5	1
88	20	6	26	8	7.1	1	16	8	3.0	1
84	24	7	26	9	5.7	2	16	9	3.7	1
80	11	9	19	11.6	5.0	3	16	11	4.4	2

METEOR WINDS OVER ATLANTA (34° N, 84° W)
FOR THE PERIOD MAY 19, 1975 TO MAY 28, 1975

EAST-WEST COMPONENTS

			24 Hour Component				12 Hour Component			
HEIGHT	MEAN	ER	AMP	ER	PHASE	ER	AMP	ER	PHASE	ER
100	36	7	11	9	17.5	4	19	10	1.0	1
96	30	6	10	8	18.8	4	11	9	.2	1
92	26	5	13	7	20.8	3	9	7	11.5	2
88	23	6	17	8	21.8	2	8	8	11.6	2
84	18	6	18	10	21.9	2	7	9	.8	2
80	12	7	12	9	20.7	4	11	10	2.7	2

NORTH-SOUTH COMPONENTS

100	6	6	5	7	7.7	7	4	9	1.2	4
96	1	6	5	9	2.8	5	7	8	5.3	2
92	- 3	5	2	6	4.9	12	16	7	5.9	1
88	- 5	5	5	7	9.9	5	21	7	6.2	1
84	- 5	6	7	7	8	5	19	8	6.6	1
80	- 5	6	18	8	3.6	2	10	8	8.2	2

METEOR WINDS OVER ATLANTA (34° N, 84° W)
FOR THE PERIOD MAY 28, 1975 TO JUNE 5, 1975

EAST-WEST COMPONENTS

			24 Hour Component				12 Hour Component			
HEIGHT	MEAN	ER	AMP	ER	PHASE	ER	AMP	ER	PHASE	ER
100	25	10	14	16	16.7	4	13	12	10.0	2
96	20	8	11	15	15.9	4	28	11	8.9	1
92	19	6	6	10	16.5	6	28	8	8.9	1
88	19	6	4	6	19.7	11	20	8	9.0	1
84	17	7	4	10	23.3	9	14	9	9	1
80	8	10	2	17	4.4	20	19	15	8.4	1

NORTH-SOUTH COMPONENTS

100	-15	9	37	15	2.8	1	27	13	8.0	1
96	-16	7	40	14	2.4	1	21	10	9	1
92	-11	6	24	11	2.2	1	10	6	11.1	2
88	- 2	6	3	9	.1	8	20	9	1.7	1
84	6	7	14	11	14.8	2	30	10	2.3	0
80	8	8	12	14	14.7	3	19	12	2.8	1

METEOR WINDS OVER ATLANTA (34° N, 84° W)
FOR THE PERIOD JUNE 5, 1975 TO JUNE 10, 1975

EAST-WEST COMPONENTS

			24 Hour Component				12 Hour Component			
HEIGHT	MEAN	ER	AMP	ER	PHASE	ER	AMP	ER	PHASE	ER
100	23	5	4	7	21.9	8	7	8	.4	2
96	26	5	9	7	3.6	2	6	6	2.6	2
92	25	4	9	6	3.7	2	8	5	2.2	1
88	23	4	5	6	2.2	3	11	6	1.2	1
84	18	4	5	6	21.6	5	15	6	.7	1
80	13	5	9	7	21.4	3	15	8	.6	1

NORTH-SOUTH

100	2	5	9	8	.2	2	1	7	2.2	10
96	1	4	10	7	1.3	2	1	6	1.3	8
92	- 2	3	12	5	2.7	1	1	4	9.9	10
88	- 6	3	15	5	4.0	1	2	5	8.2	4
84	- 9	4	16	5	4.8	1	3	5	6.1	4
80	- 9	5	15	6	6.0	2	7	6	4.4	2

METEOR WINDS OVER ATLANTA (34° N, 84° W)
FOR THE PERIOD JUNE 10, 1975 TO JUNE 19, 1975

EAST-WEST COMPONENTS

			24 Hour Component				12 Hour Component			
HEIGHT	MEAN	ER	AMP	ER	PHASE	ER	AMP	ER	PHASE	ER
100	16	5	17	8	12.9	1	4	7	2.8	3
96	17	5	12	7	13.9	2	3	7	11.7	3
92	17	4	6	5	17.3	4	6	6	.2	1
88	16	4	8	5	21.5	2	9	6	.9	1
84	13	4	10	6	21.8	2	10	6	1.4	1
80	6	5	8	7	17.4	4	7	8	1.9	2

NORTH-SOUTH COMPONENTS

100	- 3	4	12	6	8.3	2	8	6	8.5	1
96	- 1	4	13	5	8.1	2	8	6	7.5	1
92	0	3	13	4	8.2	1	6	5	6.0	2
88	- 0	3	12	5	8.6	2	7	5	4.1	1
84	- 1	4	12	5	9.4	2	8	5	3.4	1
80	- 3	5	12	8	10.4	2	4	7	3.7	3

METEOR WINDS OVER ATLANTA (34° N, 84° W)
FOR THE PERIOD JUNE 23, 1975 TO JUNE 30, 1975

EAST-WEST COMPONENTS

			24 Hour Component				12 Hour Component			
HEIGHT	MEAN	ER	AMP	ER	PHASE	ER	AMP	ER	PHASE	ER
100	29	4	7	5	21.1	3	8	5	2.4	1
96	29	3	10	5	.5	2	4	5	1.2	2
92	26	3	14	4	1.8	1	5	4	.6	1
88	22	3	16	5	2.2	1	5	4	.9	1
84	16	3	16	5	2.2	1	4	5	1.2	2
80	11	4	14	7	1.2	1	2	6	7.2	5

NORTH-SOUTH COMPONENTS

100	1	3	7	5	11.1	3	5	4	9.3	2
96	0	3	3	4	14.4	5	10	4	10.0	1
92	- 1	2	2	3	16.7	7	7	3	10.6	1
88	- 2	3	1	4	16.7	14	3	4	1.3	2
84	- 3	3	1	4	18.4	21	6	4	2.7	1
80	- 4	4	4	5	20.2	6	3	5	1.8	3

METEOR WINDS OVER ATLANTA (34° N, 84° W)
FOR THE PERIOD JULY 1, 1975 TO JULY 9, 1975

EAST-WEST COMPONENTS

			24 Hour Component				12 Hour Component			
HEIGHT	MEAN	ER	AMP	ER	PHASE	ER	AMP	ER	PHASE	ER
100	30	4	3	7	13.5	6	13	6	11.0	1
96	32	4	4	5	18.7	6	7	5	11.0	2
92	33	3	6	4	19.1	3	4	5	.6	2
88	32	3	7	4	19.0	3	7	5	2.0	1
84	28	4	6	5	19.8	4	11	6	1.9	1
80	19	6	6	9	23.5	5	15	9	1.4	1

NORTH-SOUTH COMPONENTS

100	2	4	4	5	5.9	6	6	5	12.0	2
96	3	3	1	4	17.1	17	5	5	1.2	2
92	3	3	2	4	17.0	8	6	4	1.2	1
88	4	3	1	4	12.8	12	5	4	.7	1
84	4	3	3	5	10.5	5	4	4	11.7	2
80	6	4	7	7	11.6	3	4	6	8.4	3

METEOR WINDS OVER ATLANTA (34° N, 84° W)
FOR THE PERIOD JULY 9, 1975 TO JULY 18, 1975

			24 Hour Component				12 Hour Component			
HEIGHT	MEAN	ER	AMP	ER	PHASE	ER	AMP	ER	PHASE	ER
EAST-WEST COMPONENTS										
100	29	4	2	5	8.4	10	9	6	4.7	1
96	28	4	1	5	17.7	42	12	6	4.3	1
92	27	3	5	6	.0	3	8	5	4.4	1
88	25	4	10	6	.6	2	2	5	6.0	4
84	20	4	13	7	.6	1	4	5	9.2	3
80	12	5	9	8	23.7	3	3	7	10.4	4
NORTH-SOUTH COMPONENTS										
100	0	4	11	6	13.2	2	9	5	3.4	1
96	4	4	11	6	14.2	1	14	5	2.7	1
92	4	3	4	4	15.7	4	12	4	2.5	1
88	2	3	6	5	.9	2	5	4	2.6	2
84	0	3	12	5	2.0	1	3	5	7.8	3
80	1	4	11	6	2.8	2	8	6	7.9	1

METEOR WINDS OVER ATLANTA (34° N, 84° W)
FOR THE PERIOD JULY 18, 1975 TO JULY 23, 1975

EAST-WEST COMPONENTS

			24 Hour Component				12 Hour Component			
HEIGHT	MEAN	ER	AMP	ER	PHASE	ER	AMP	ER	PHASE	ER
100	27	4	3	6	2.2	7	10	6	11.9	1
96	31	4	1	6	1.9	13	11	5	.2	1
92	27	3	1	4	4.6	11	3	4	11.3	3
88	19	3	1	4	8.7	17	10	5	7.2	1
84	13	4	5	6	14.8	4	18	6	7.1	0
80	11	5	16	8	15.8	2	18	8	7.4	1

NORTH-SOUTH COMPONENTS

100	- 9	3	2	5	2.1	8	9	5	9.2	1
96	- 5	3	4	4	17.4	4	3	4	11.3	3
92	- 0	2	4	4	17.2	3	7	4	2.2	1
88	3	3	2	4	17.3	8	11	4	2.5	1
84	4	3	3	4	6.3	5	12	4	2.6	1
80	0	4	10	6	6.7	2	8	6	2.2	1

METEOR WINDS OVER ATLANTA (34° N, 84° W)
FOR THE PERIOD JULY 23, 1975 TO JULY 28, 1975

EAST-WEST COMPONENTS

			24 Hour Component				12 Hour Component			
HEIGHT	MEAN	ER	AMP	ER	PHASE	ER	AMP	ER	PHASE	ER
100	22	5	17	7	10.2	1	1	6	3.7	13
96	21	4	23	6	10.3	1	5	6	5.0	2
92	20	4	20	5	10.4	1	5	5	5.3	2
88	17	4	11	6	11.1	2	4	6	5.8	3
84	11	4	5	7	14.8	4	3	7	6.0	3
80	1	6	9	9	17.2	3	6	9	5.2	3

NORTH-SOUTH COMPONENTS

100	- 4	4	4	6	6.5	5	2	5	10.3	5
96	- 4	4	8	5	5.9	2	2	6	.3	4
92	- 2	3	10	4	6.5	2	7	4	3.0	1
88	1	3	11	4	7.4	2	13	4	3.4	1
84	5	4	12	5	8.2	2	14	5	3.4	1
80	7	4	13	6	8.5	2	6	6	2.3	2

METEOR WINDS OVER ATLANTA (34° N, 84° W)
FOR THE PERIOD JULY 29, 1975 TO AUGUST 4, 1975

EAST-WEST COMPONENTS

			24 Hour Component				12 Hour Component			
HEIGHT	MEAN	ER	AMP	ER	PHASE	ER	AMP	ER	PHASE	ER
100	28	6	9	6	18.7	4	7	7	4.1	2
96	31	5	8	6	18.0	3	6	6	4.6	2
92	30	4	8	6	15.6	3	4	5	4.7	3
88	26	4	11	7	13.4	2	1	6	2.4	13
84	20	5	14	8	13.0	2	5	7	11.5	2
80	12	7	16	11	13.8	2	13	9	11.3	2

NORTH-SOUTH COMPONENTS

100	- 6	5	10	7	14.3	2	4	7	1.6	3
96	- 6	4	7	6	13.8	2	7	6	1.5	1
92	- 3	3	2	5	13.6	6	10	5	1.8	1
88	1	3	3	6	1.7	4	12	5	2.1	1
84	3	4	9	7	1.8	2	14	6	2.3	1
80	1	6	15	9	2.0	2	14	9	2.4	1

METEOR WINDS OVER ATLANTA (34° N, 84° W)
FOR THE PERIOD AUGUST 6, 1975 TO AUGUST 15, 1975

EAST-WEST COMPONENTS

			24 Hour Component				12 Hour Component			
HEIGHT	MEAN	ER	AMP	ER	PHASE	ER	AMP	ER	PHASE	ER
100	30	7	15	12	.5	2	4	10	1.5	4
96	28	7	8	9	2.4	5	4	9	1.6	4
92	22	5	10	9	11.3	3	3	7	5.6	5
88	15	5	25	8	12.3	1	10	8	6.1	2
84	11	6	29	9	12.2	1	12	8	5.5	2
80	11	8	16	12	10.1	3	17	12	3.5	1

NORTH-SOUTH COMPONENTS

100	- 9	6	23	8	13.8	1	18	8	5.5	1
96	- 4	5	14	8	13.9	2	14	7	4.9	1
92	1	4	1	6	21.4	31	11	5	4.1	1
88	3	4	12	6	1.8	2	10	5	3.4	1
84	3	5	15	7	2.2	2	10	6	3.7	1
80	- 2	6	6	9	6.8	6	13	8	5.0	1

METEOR WINDS OVER ATLANTA (34° N, 84° W)
FOR THE PERIOD AUGUST 15, 1975 TO SEPTEMBER 9, 1975

EAST-WEST COMPONENTS

			24 Hour Component				12 Hour Component			
HEIGHT	MEAN	ER	AMP	ER	PHASE	ER	AMP	ER	PHASE	ER
100	23	15	32	24	4.8	2	25	21	11.3	2
96	33	12	12	17	3.5	5	21	16	11.4	2
92	32	10	10	15	2.9	5	17	13	10.8	2
88	28	11	14	17	4.0	4	13	15	9.6	3
84	26	12	17	19	4.7	4	12	20	7.3	3
80	31	23	7	30	5.7	20	30	33	5.2	2

NORTH-SOUTH COMPONENTS

100	3	11	37	15	15.3	1	40	14	5.5	1
96	1	9	29	13	14.4	1	37	12	6.1	1
92	-12	8	17	12	11.8	2	18	12	6.5	1
88	-23	9	17	12	8.0	3	5	12	9.8	6
84	-22	9	12	13	6.7	4	9	12	9.6	3
80	3	20	19	32	17.2	5	41	26	7.3	1

METEOR WINDS OVER ATLANTA (34° N, 84° W)
FOR THE PERIOD SEPTEMBER 9, 1975 TO SEPTEMBER 19, 1975

EAST-WEST COMPONENTS

			24 Hour Component				12 Hour Component			
HEIGHT	MEAN	ER	AMP	ER	PHASE	ER	AMP	ER	PHASE	ER
100	42	7	22	12	3.6	2	16	12	2.3	1
96	39	6	28	10	3.6	1	10	11	2.3	2
92	35	5	25	9	2.7	1	14	8	2.5	1
88	29	6	20	10	.5	1	20	9	2.5	1
84	22	7	20	9	21.0	2	18	11	2.4	1
80	14	9	29	12	17.9	2	4	12	10.1	7

NORTH-SOUTH COMPONENTS

100	1	5	7	9	7.4	5	12	7	5.6	1
96	1	4	7	6	8.0	3	12	7	6.9	1
92	3	4	9	5	10.0	2	12	6	7.9	1
88	6	5	12	6	11.1	2	12	7	8.9	1
84	8	5	12	7	10.8	2	10	7	9.7	1
80	11	6	9	8	7.0	4	4	8	10.3	5

METEOR WINDS OVER ATLANTA (34° N, 84° W)
FOR THE PERIOD SEPTEMBER 19, 1975 TO SEPTEMBER 25, 1975

EAST-WEST COMPONENTS

			24 Hour Component				12 Hour Component			
HEIGHT	MEAN	ER	AMP	ER	PHASE	ER	AMP	ER	PHASE	ER
100	41	7	21	10	2.3	2	22	10	3.2	1
96	36	7	19	10	1.6	2	18	9	3.1	1
92	35	5	14	8	1.3	2	14	8	2.1	1
88	34	6	7	9	1.0	4	13	8	.9	1
84	32	7	1	10	18.2	42	9	10	12.0	2
80	24	9	7	12	14.5	7	12	12	7.2	2

NORTH-SOUTH COMPONENTS

100	1	5	3	7	12.9	8	6	7	4.4	3
96	- 0	4	4	6	6.5	6	6	6	4.7	2
92	0	4	9	5	6.0	2	8	5	4.9	1
88	1	4	11	6	6.3	2	9	6	4.9	1
84	2	5	9	6	7.1	3	8	7	4.7	2
80	- 0	6	4	9	12.3	7	3	8	2.7	6

METEOR WINDS OVER ATLANTA (34° N, 84° W)
FOR THE PERIOD SEPTEMBER 25, 1975 TO SEPTEMBER 30, 1975

EAST-WEST COMPONENTS

			24 Hour Component				12 Hour Component			
HEIGHT	MEAN	ER	AMP	ER	PHASE	ER	AMP	ER	PHASE	ER
100	23	8	4	14	1.0	8	11	12	8.8	2
96	28	8	9	13	23.2	4	2	11	1.8	10
92	34	6	16	10	23.8	2	15	8	2.4	1
88	38	6	19	9	.4	2	24	8	2.4	1
84	36	7	15	11	1.6	2	24	10	2.4	1
80	23	8	10	9	8.0	5	11	11	2.4	2

NORTH-SOUTH COMPONENTS

100	1	6	12	7	9.0	3	10	7	4.1	2
96	- 1	5	4	6	8.1	8	7	7	3.6	2
92	- 3	4	3	6	10.1	8	2	6	3.6	5
88	- 4	4	5	6	11.1	4	2	6	7.9	4
84	- 3	5	6	7	10.3	5	6	7	7.4	2
80	2	6	5	8	5.0	6	10	8	6.2	1

METEOR WINDS OVER ATLANTA (34° N, 84° W)
FOR THE PERIOD SEPTEMBER 30, 1975 TO OCTOBER 4, 1975

EAST-WEST COMPONENTS

			24 Hour Component				12 Hour Component			
HEIGHT	MEAN	ER	AMP	ER	PHASE	ER	AMP	ER	PHASE	ER
100	28	7	6	9	19.1	8	13	10	10.3	2
96	33	6	4	10	.7	7	5	8	11.2	4
92	41	5	18	8	4.1	2	8	7	3.4	2
88	47	6	25	10	4.4	1	18	9	3.7	1
84	44	7	23	12	3.9	1	23	11	3.4	1
80	27	10	14	12	21.7	4	22	14	2.4	1

NORTH-SOUTH COMPONENTS

100	12	5	14	7	7.5	2	10	7	4.9	2
96	16	5	9	7	2.4	3	12	7	3.6	1
92	9	4	8	6	22.6	3	7	6	3.5	2
88	- 1	4	8	6	18.4	3	3	6	7.4	3
84	- 6	5	8	8	13.9	3	9	7	7.9	1
80	- 0	7	16	9	8.7	2	9	9	6.6	2

METEOR WINDS OVER ATLANTA (34° N, 84° W)
FOR THE PERIOD OCTOBER 4, 1975 TO OCTOBER 9, 1975

EAST-WEST COMPONENTS

			24 Hour Component				12 Hour Component			
HEIGHT	MEAN	ER	AMP	ER	PHASE	ER	AMP	ER	PHASE	ER
100	31	8	7	10	14.0	6	6	11	10.5	3
96	40	6	8	8	7.9	4	7	7	11.7	2
92	43	5	14	6	7.0	2	8	6	.4	2
88	40	5	16	6	6.7	2	8	8	1.3	2
84	31	6	16	8	6.0	2	8	8	3.2	2
80	18	9	17	13	4.1	3	19	13	4.6	1

NORTH-SOUTH COMPONENTS

100	- 4	6	15	10	19.8	2	8	10	2.7	2
96	- 0	4	11	7	21.2	2	10	7	3.0	1
92	0	3	9	5	21.2	2	8	5	4.1	1
88	1	4	6	5	20.3	4	10	5	5.7	1
84	2	5	2	6	19.6	12	12	6	6.7	1
80	9	7	6	9	5.3	6	11	10	7.6	2

METEOR WINDS OVER ATLANTA (34° N, 84° W)
FOR THE PERIOD OCTOBER 9. 1975 TO OCTOBER 12, 1975

EAST-WEST COMPONENTS

			24 Hour Component				12 Hour Component			
HEIGHT	MEAN	ER	AMP	ER	PHASE	ER	AMP	ER	PHASE	ER
100	37	7	6	9	5.6	6	8	10	2.4	2
96	40	6	10	8	2.1	4	8	8	2.1	2
92	35	5	3	8	1.7	8	7	8	10.8	2
88	28	6	6	10	12.7	4	16	8	9.8	1
84	22	7	11	11	11.9	3	16	9	9.7	1
80	21	9	10	11	7.3	5	5	12	2.9	5

NORTH-SOUTH COMPONENTS

100	- 7	5	6	8	22.3	5	3	8	8.7	5
96	- 2	5	6	8	10.1	4	9	7	6.3	1
92	4	4	10	5	6.0	2	15	6	6.1	1
88	- 9	4	19	6	3.5	1	17	6	6.0	1
84	12	5	26	7	2.5	1	15	7	6.0	1
80	10	6	21	9	1.7	1	7	9	5.9	2

METEOR WINDS OVER ATLANTA (34° N, 84° W)
FOR THE PERIOD OCTOBER 12, 1975 TO OCTOBER 15, 1975

EAST-WEST COMPONENTS

			24 Hour Component				12 Hour Component			
HEIGHT	MEAN	ER	AMP	ER	PHASE	ER	AMP	ER	PHASE	ER
100	25	10	26	15	10.3	2	19	12	.9	1
96	27	8	26	13	9.8	1	27	12	1.6	1
92	30	7	18	10	10.0	2	19	10	2.0	1
88	31	7	13	11	11.5	3	9	10	4.1	2
84	24	10	22	16	12.3	2	21	12	5.8	1
80	6	19	51	33	11.7	1	38	24	5.4	1

NORTH-SOUTH COMPONENTS

100	- 6	8	11	12	19.5	4	15	12	9.7	1
96	7	7	19	10	17.8	2	20	11	8.7	1
92	9	6	16	8	16.0	2	22	9	7.8	1
88	5	6	12	8	13.0	3	22	8	7.1	1
84	4	7	7	10	7.9	4	16	8	6.4	1
80	12	10	23	16	1.1	2	6	11	2.1	4

METEOR WINDS OVER ATLANTA (34° N, 84° W)
FOR THE PERIOD OCTOBER 15, 1975 TO OCTOBER 24, 1975

EAST-WEST COMPONENTS

			24 Hour Component				12 Hour Component			
HEIGHT	MEAN	ER	AMP	ER	PHASE	ER	AMP	ER	PHASE	ER
100	30	9	21	12	16.1	2	11	11	10.8	2
96	31	8	13	11	16.0	3	5	10	10.2	4
92	29	7	6	11	13.5	5	0	9	10.1	39
88	25	8	8	13	10.0	5	3	10	3.0	9
84	23	9	11	14	10.2	4	3	12	2.1	7
80	24	11	13	18	13.2	4	5	18	11.1	6

NORTH-SOUTH COMPONENTS

100	- 9	7	24	10	9.9	1	9	8	4.8	2
96	- 6	6	20	10	10.4	2	6	8	4.1	3
92	0	6	11	8	9.4	3	7	8	5.4	2
88	7	6	9	7	5.8	5	13	10	6.0	1
84	10	7	14	8	5.7	3	21	10	5.8	1
80	5	9	24	12	8.5	2	29	12	5.1	1

METEOR WINDS OVER ATLANTA (34° N, 84° W)
FOR THE PERIOD OCTOBER 24, 1975 TO NOVEMBER 3, 1975

EAST-WEST COMPONENTS

			24 Hour Component				12 Hour Component			
HEIGHT	MEAN	ER	AMP	ER	PHASE	ER	AMP	ER	PHASE	ER
100	34	9	6	15	7.7	6	5	12	.1	4
96	35	7	5	11	16.8	8	6	9	5.3	3
92	37	5	5	7	17.1	5	8	7	5.0	2
88	37	6	2	7	15.6	21	6	8	3.6	3
84	34	7	1	11	6.4	30	9	12	1.6	2
80	27	10	4	17	19.8	13	16	17	.9	1

NORTH-SOUTH COMPONENTS

100	5	7	25	12	8.2	1	17	10	8.7	1
96	7	6	22	10	8.7	1	24	8	9.2	1
92	5	5	19	7	8.1	1	21	6	9.9	1
88	1	5	18	7	7.5	1	16	6	10.8	1
84	- 2	6	14	9	8.3	2	9	7	10.8	2
80	- 3	8	17	11	12.2	3	19	16	7.6	1

METEOR WINDS OVER ATLANTA (34° N, 84° W)
FOR THE PERIOD NOVEMBER 3, 1975 TO NOVEMBER 13, 1975

EAST-WEST COMPONENTS

			24 Hour Component				12 Hour Component			
HEIGHT	MEAN	ER	AMP	ER	PHASE	ER	AMP	ER	PHASE	ER
100	37	3	4	4	20.5	6	4	4	5.9	2
96	39	3	1	5	1.0	11	7	4	5.1	1
92	40	2	4	4	2.3	3	7	3	4.8	1
88	38	3	6	4	1.6	2	6	4	4.3	1
84	35	3	6	5	1.2	2	5	4	3.4	2
80	31	4	2	6	.9	10	7	6	2.7	1

NORTH-SOUTH COMPONENTS

100	4	3	6	4	3.9	2	9	4	3.9	1
96	4	2	6	3	9.6	3	10	3	4.1	1
92	4	2	7	3	11.3	2	8	3	4.3	1
88	4	2	6	3	11.8	2	7	3	4.6	1
84	5	2	4	3	10.6	4	6	3	5.0	1
80	5	3	6	4	6.7	3	7	4	5.2	1

METEOR WINDS OVER ATLANTA (34° N, 84° W)
FOR THE PERIOD NOVEMBER 13, 1975 TO NOVEMBER 20, 1975

EAST-WEST COMPONENTS

			24 Hour Component				12 Hour Component			
HEIGHT	MEAN	ER	AMP	ER	PHASE	ER	AMP	ER	PHASE	ER
100	33	5	8	8	.3	3	6	7	2.5	2
96	35	4	10	6	.0	2	8	6	2.0	1
92	37	4	10	5	.6	2	4	4	11.8	2
88	36	4	9	6	1.6	2	10	5	9.8	1
84	31	4	7	8	2.8	3	14	6	9.5	1
80	23	6	3	8	6	14	6	8	10.3	2

NORTH-SOUTH COMPONENTS

100	3	4	5	7	15.1	4	7	6	9.7	2
96	- 1	4	11	6	15.9	2	8	5	9.9	1
92	- 2	3	12	5	16.3	1	3	4	9.6	2
88	- 1	3	8	5	16.9	2	3	4	4.7	3
84	1	4	2	5	22.4	12	7	5	4.5	2
80	4	5	11	8	3.7	2	4	6	5.0	3

METEOR WINDS OVER ATLANTA (34° N, 84° W)
FOR THE PERIOD NOVEMBER 20, 1975 TO NOVEMBER 27, 1975

EAST-WEST COMPONENTS

			24 Hour Component				12 Hour Component			
HEIGHT	MEAN	ER	AMP	ER	PHASE	ER	AMP	ER	PHASE	ER
100	37	4	12	7	2.8	1	5	6	4.2	2
96	38	4	16	6	3.4	1	5	5	6.3	2
92	38	3	20	5	3.6	1	4	4	7.6	2
88	35	3	22	5	3.6	1	3	4	8.8	2
84	30	4	20	6	3.5	1	3	5	8.0	3
80	23	4	14	7	2.9	1	9	6	6.1	1

NORTH-SOUTH COMPONENTS

100	4	3	8	5	11.1	2	3	5	7.0	3
96	4	3	7	4	10.8	2	6	4	9.0	1
92	3	2	5	3	8.9	3	6	4	9.4	1
88	1	3	5	4	5.3	3	4	4	9.3	2
84	- 1	3	6	5	4.6	2	4	4	6.9	2
80	- 3	4	6	5	7.4	4	13	5	6.4	1

METEOR WINDS OVER ATLANTA (34° N, 84°W)
FOR THE PERIOD NOVEMBER 27, 1975 TO DECEMBER 2, 1975

EAST WEST COMPONENTS

			24 Hour Component				12 Hour Component			
HEIGHT	MEAN	ER	AMP	ER	PHASE	ER	AMP	ER	PHASE	ER
100	38	4	4	6	1.9	5	14	5	5.3	1
96	33	3	7	5	16.9	2	12	4	6.4	1
92	31	3	6	4	16.7	2	6	4	6.8	1
88	30	3	1	4	18.4	12	2	4	1.9	3
84	30	3	5	5	3.7	3	8	4	1.8	1
80	31	4	6	6	3.9	3	9	6	2.6	1

NORTH-SOUTH COMPONENTS

100	2	3	8	4	6.2	2	3	4	4.0	2
96	1	3	4	4	7.3	3	2	4	2.8	3
92	2	2	5	3	3.5	2	6	3	2.4	1
88	4	2	11	4	2.1	1	9	3	2.5	1
84	5	3	13	4	1.7	1	9	4	2.7	1
80	2	3	6	5	1.2	2	3	4	4.5	3

METEOR WINDS OVER ATLANTA (34° N, 84° W)
FOR THE PERIOD DECEMBER 2, 1975 TO DECEMBER 6, 1975

EAST-WEST COMPONENTS

			24 Hour Component				12 Hour Component			
HEIGHT	MEAN	ER	AMP	ER	PHASE	ER	AMP	ER	PHASE	ER
100	28	7	8	10	10.9	5	12	8	4.0	2
96	30	6	2	9	10.6	16	5	7	5.4	4
92	34	5	5	8	23.2	5	4	6	10.4	4
88	38	5	12	8	23.0	2	11	6	11.4	1
84	37	6	16	9	22.8	2	13	7	11.8	1
80	26	9	16	13	22.4	3	6	13	.9	3

NORTH-SOUTH COMPONENTS

100	- 8	6	20	9	2.6	1	9	8	2.8	1
96	- 4	5	22	8	3.0	1	7	7	3.4	2
92	1	4	17	7	3.6	1	5	5	4.6	2
88	5	5	12	6	4.7	2	4	6	5.6	3
84	8	5	12	6	5.7	2	3	6	4.7	5
80	10	7	22	8	5.1	2	9	9	2.1	2

METEOR WINDS OVER ATLANTA (34° N, 84°W)
FOR THE PERIOD DECEMBER 6, 1975 TO DECEMBER 12, 1975

EAST-WEST COMPONENTS

			24 Hour Component				12 Hour Component			
HEIGHT	MEAN	ER	AMP	ER	PHASE	ER	AMP	ER	PHASE	ER
100	48	9	24	16	12.4	1	21	12	2.4	1
96	42	8	18	14	12.8	1	15	9	2.9	1
92	37	6	13	10	14.8	2	13	7	3.3	1
88	34	7	15	8	17.1	3	12	7	3.3	1
84	35	8	18	9	17.4	3	10	9	2.7	2
80	40	13	18	18	15.5	3	11	17	.7	2

NORTH-SOUTH COMPONENTS

100	10	8	9	13	12.3	3	16	9	11.9	1
96	9	6	8	6	8.9	5	17	8	12.0	1
92	7	5	5	5	7.0	6	12	6	11.9	1
88	6	6	3	10	2.6	6	6	6	11.7	2
84	7	6	6	11	23.9	4	3	8	.2	5
80	11	9	9	15	1.1	3	10	11	.9	1

METEOR WINDS OVER ATLANTA (34° N, 84° W)
FOR THE PERIOD DECEMBER 12, 1975 TO CEOMBER 18, 1975

EAST-WEST COMPONENTS

			24 Hour Component				12 Hour Component			
HEIGHT	MEAN	ER	AMP	ER	PHASE	ER	AMP	ER	PHASE	ER
100	23	7	10	9	21.5	4	11	10	8.9	1
96	22	6	13	8	23.2	2	10	9	7.9	1
92	23	5	17	7	22.0	2	4	6	5.3	3
88	24	6	19	7	20.6	2	12	8	2.9	1
84	24	6	17	8	19.2	2	15	10	2.3	1
80	21	8	7	11	13.4	6	8	11	.5	3

NORTH-SOUTH COMPONENTS

100	3	6	11	8	10.2	3	7	8	6.8	2
96	1	5	13	6	7.9	2	9	7	6.6	1
92	1	4	14	5	7.9	2	5	6	6.5	2
88	2	4	13	6	8.5	2	2	6	.3	6
84	2	5	6	7	8.2	4	7	7	12.0	2
80	0	5	11	8	23.8	3	7	8	10.8	2

METEOR WINDS OVER ATLANTA (34° N, 84° W)
FOR THE PERIOD DECEMBER 18, 1975 TO DECEMBER 25, 1975

EAST-WEST COMPONENTS

			24 Hour Component				12 Hour Component			
HEIGHT	MEAN	ER	AMP	ER	PHASE	ER	AMP	ER	PHASE	ER
100	18	7	7	10	14.5	4	14	9	8.4	1
96	17	6	13	9	15.4	3	6	8	8.0	3
92	18	5	14	7	15.7	2	3	6	8.9	4
88	28	6	12	8	15.9	3	6	7	9.7	3
84	23	6	9	8	15.7	4	9	8	9.8	2
80	25	8	6	12	14.4	6	13	12	8.3	1

NORTH-SOUTH COMPONENTS

100	17	6	8	6	6.8	5	6	7	8	2
96	17	5	5	5	6.4	6	5	6	4.5	3
92	13	4	5	6	2.7	4	4	5	3.3	3
88	7	5	6	8	.8	3	3	6	.1	3
84	1	5	2	7	22.1	14	8	6	10.6	2
80	- 6	6	16	8	12.8	2	11	8	10.0	1

METEOR WINDS OVER ATLANTA (34° N, 84° W)
FOR THE PERIOD DECEMBER 25, 1975 TO DECEMBER 31, 1975

EAST-WEST COMPONENTS

			24 Hour Component				12 Hour Component			
HEIGHT	MEAN	ER	AMP	ER	PHASE	ER	AMP	ER	PHASE	ER
100	17	6	23	8	9.6	2	11	8	6.5	2
96	24	5	11	7	9.4	3	9	8	7.2	2
92	25	4	6	7	14.8	4	7	7	8.3	2
88	25	5	12	7	17.3	2	4	7	9.8	3
84	26	5	12	7	18.2	3	9	8	1.6	1
80	31	10	8	16	1.8	5	31	15	2.3	1

NORTH-SOUTH COMPONENTS

100	- 2	5	23	7	10.7	1	15	6	5.8	1
96	6	4	17	6	9.9	1	11	6	6.4	1
92	8	4	14	5	8.3	1	10	5	6.1	1
88	6	4	14	5	7.0	2	12	5	5.7	1
84	2	5	13	6	6.7	2	12	6	5.5	1
80	- 1	7	8	9	8.3	6	7	10	6.0	3

METEOR WINDS OVER ATLANTA (34° N, 84° W)
FOR THE PERIOD JANUARY 1, 1976 TO JANUARY 4, 1976

EAST-WEST COMPONENTS

			24 Hour Component				12 Hour Component			
HEIGHT	MEAN	ER	AMP	ER	PHASE	ER	AMP	ER	PHASE	ER
100	22	8	8	12	5.8	6	12	12	3.4	2
96	20	8	8	11	9.6	5	9	11	4.4	2
92	15	6	5	9	18.5	8	3	9	4.2	5
88	12	7	16	9	20.8	2	4	10	.9	5
84	13	7	15	11	21.6	3	5	11	1.2	4
80	20	10	14	13	7.7	4	9	13	4.1	3

NORTH-SOUTH COMPONENTS

100	4	7	26	10	3.5	1	6	10	10.2	3
96	6	7	26	10	3.5	1	13	9	11.0	1
92	8	5	21	8	3.7	1	8	8	11.7	2
88	9	6	15	8	3.9	2	4	8	2.9	3
84	9	6	14	9	2.7	2	6	9	4.6	3
80	5	8	26	12	1.2	2	8	12	9.2	3

METEOR WINDS OVER ATLANTA (34° N, 84° W)
FOR THE PERIOD JANUARY 5, 1975 TO JANUARY 10, 1976

EAST-WEST COMPONENTS

			24 Hour Component				12 Hour Component			
HEIGHT	MEAN	ER	AMP	ER	PHASE	ER	AMP	ER	PHASE	ER
100	12	8	15	11	17.9	3	10	11	10.7	2
96	9	7	16	11	16.5	2	11	11	.2	2
92	2	6	19	9	12.9	2	7	9	1.1	2
88	- 4	6	28	9	10.9	1	3	9	3.4	6
84	- 5	7	28	10	10.4	1	4	10	7.3	5
80	4	8	6	12	14.8	8	14	12	9.6	2

NORTH-SOUTH COMPONENTS

HEIGHT	MEAN	ER	AMP	ER	PHASE	ER	AMP	ER	PHASE	ER
100	- 1	7	9	10	3.5	4	11	10	7.3	2
96	0	7	10	9	23.2	4	16	9	8.6	1
92	2	6	8	8	20.8	4	11	8	8.7	1
88	4	6	8	8	15.8	4	3	8	6.9	5
84	5	6	19	9	12.7	2	9	9	4.6	2
80	5	7	35	11	11.7	1	12	10	5.5	2

METEOR WINDS OVER ATLANTA (34° N, 84° W)
FOR THE PERIOD JANUARY 11, 1976 TO JANUARY 19, 1976

EAST-WEST COMPONENTS

			24 Hour Component				12 Hour Component			
HEIGHT	MEAN	ER	AMP	ER	PHASE	ER	AMP	ER	PHASE	ER
100	17	11	5	18	3.8	11	17	16	4.5	2
96	9	10	5	14	2.6	11	25	15	5.3	1
92	6	8	4	11	19.1	11	21	13	5.3	1
88	7	8	9	11	16.8	5	11	12	4.7	2
84	10	9	7	13	12.4	7	8	12	2.1	3
80	12	12	29	16	7.2	3	10	18	1.4	3

NORTH-SOUTH COMPONENTS

100	3	9	11	14	14.1	4	14	14	8.4	2
96	6	9	1	12	19.9	33	7	12	8.1	4
92	12	8	8	11	1.9	5	3	10	2.1	6
88	17	7	13	10	2.5	3	9	9	2.1	2
84	16	8	12	11	2.5	3	3	11	3.8	7
80	7	10	4	17	.3	10	26	14	7.4	1

METEOR WINDS OVER ATLANTA (34° N, 84° W)
FOR THE PERIOD JANUARY 18, 1976 TO JANUARY 31, 1976

EAST-WEST COMPONENTS

			24 Hour Component				12 Hour Component			
HEIGHT	MEAN	ER	AMP	ER	PHASE	ER	AMP	ER	PHASE	ER
100	20	12	20	19	24.0	3	10	16	6.9	3
96	19	10	7	12	6.6	10	29	14	6.4	1
92	17	8	9	11	10.0	5	33	11	6.3	1
88	15	8	8	13	12.6	5	26	11	6.2	1
84	16	9	11	16	13.8	4	12	13	6.2	2
80	20	13	20	19	12.1	3	6	17	10.5	5

NORTH-SOUTH COMPONENTS

100	-10	10	22	16	14.8	2	28	14	7.5	1
96	0	9	11	14	14.0	4	13	13	7.1	2
92	4	7	5	10	10.9	8	6	9	11.0	3
88	5	7	6	9	7.2	6	19	9	11.7	1
84	4	7	8	9	7.4	6	20	10	11.9	1
80	3	10	11	12	9.8	5	6	14	2.8	4

METEOR WINDS OVER ATLANTA (34° N, 84° W)
FOR THE PERIOD JANUARY 31, 1976 TO FEBRUARY 6, 1976

EAST-WEST COMPONENTS

			24 Hour Component				12 Hour Component			
HEIGHT	MEAN	ER	AMP	ER	PHASE	ER	AMP	ER	PHASE	ER
100	-10	21	56	37	15.1	2	59	35	8.3	1
96	5	15	32	19	18.4	3	45	23	8.7	1
92	11	13	27	15	19.9	3	35	18	9.1	1
88	10	12	15	15	18.6	5	28	18	9.3	1
84	6	14	18	23	12.9	4	24	22	9.1	1
80	3	17	38	24	11.0	3	26	27	8.5	1

NORTH-SOUTH COMPONENTS

100	- 5	14	19	24	15.7	4	39	24	8.1	1
96	- 8	13	11	21	3.8	6	13	20	7.3	2
92	-10	11	11	16	4.9	6	9	13	4.7	4
88	-11	10	8	14	10.5	7	14	13	4.1	2
84	- 9	11	12	17	12.1	5	17	15	4.0	2
80	- 2	14	15	21	5.9	5	21	21	3.9	2

METEOR WINDS OVER ATLANTA (34° N, 84° W)
FOR THE PERIOD FEBRUARY 6, 1976 TO FEBRUARY 12, 1976

EAST-WEST COMPONENTS

			24 Hour Component				12 Hour Component			
HEIGHT	MEAN	ER	AMP	ER	PHASE	ER	AMP	ER	PHASE	ER
100	15	19	2	28	7.5	41	12	31	4.6	3
96	25	15	20	21	20.7	4	31	19	7.5	1
92	18	13	15	18	21.8	4	34	18	7.6	1
88	3	13	11	18	4.8	7	21	19	7.5	2
84	- 9	15	32	19	7.4	3	2	21	6.6	18
80	- 9	19	48	25	8.3	2	14	29	1.0	3

NORTH-SOUTH COMPONENTS

100	4	22	3	21	6.0	45	20	25	6.3	2
96	-19	15	26	17	7.3	4	18	19	5.3	2
92	-23	11	34	13	6.1	2	14	14	3.8	2
88	-16	10	34	14	4.8	2	17	15	2.2	2
84	- 8	12	24	16	3.8	3	18	17	1.5	2
80	- 6	14	6	21	13.9	11	7	18	1.1	5

METEOR WINDS OVER ATLANTA (34° N, 84° W)
FOR THE PERIOD FEBRUARY 24, 1976 TO MARCH 4, 1976

EAST-WEST COMPONENTS

			24 Hour Component				12 Hour Component			
HEIGHT	MEAN	ER	AMP	ER	PHASE	ER	AMP	ER	PHASE	ER
100	37	8	3	12	5.0	14	14	10	5.5	2
96	28	7	9	12	3	4	10	9	4.6	2
92	26	6	4	10	23.7	9	10	9	2.9	2
88	28	6	6	9	10.3	7	14	10	2.1	1
84	29	7	11	8	7.6	4	19	12	2.1	1
80	28	11	30	20	3.9	2	21	19	2.5	1

NORTH-SOUTH COMPONENTS

100	3	6	15	10	1.4	2	9	9	.7	2
96	8	6	10	10	1.4	3	10	8	11.6	2
92	10	5	2	8	1.8	10	5	7	9.6	3
88	10	5	5	9	13.8	5	11	8	6.9	1
84	7	6	10	9	14.9	3	17	9	6.3	1
80	3	8	12	11	17.3	4	10	11	5.9	2

METEOR WINDS OVER ATLANTA (34° N, 84° W)
FOR THE PERIOD MARCH 12, 1976 TO MARCH 16, 1976

EAST-WEST COMPONENTS

			24 Hour Component				12 Hour Component			
HEIGHT	MEAN	ER	AMP	ER	PHASE	ER	AMP	ER	PHASE	ER
100	26	14	7	19	13.8	12	30	17	4.2	1
96	30	10	3	16	11.9	17	10	14	3.8	3
92	27	9	8	13	4.3	6	3	14	8.0	6
88	19	10	16	15	3.7	3	11	14	8.1	2
84	11	11	20	16	3.8	3	14	16	7.7	2
80	3	13	13	18	5.1	6	8	18	6.6	5

NORTH-SOUTH COMPONENTS

100	-18	12	3	16	15.3	25	30	16	6.2	1
96	-14	8	8	12	11.8	5	14	12	6.4	2
92	- 7	7	7	10	11.4	5	6	10	4.9	3
88	0	8	3	11	11.0	16	10	11	3.5	2
84	3	8	1	12	22.4	36	12	12	3.8	2
80	- 2	12	2	16	18	39	8	16	5.8	4

METEOR WINDS OVER ATLANTA (34° N, 84° W)
FOR THE PERIOD MARCH 17, 1976 TO MARCH 21, 1976

EAST-WEST COMPONENTS

			24 Hour Component				12 Hour Component			
HEIGHT	MEAN	ER	AMP	ER	PHASE	ER	AMP	ER	PHASE	ER
100	29	19	12	20	6.2	10	17	24	8.8	3
96	33	14	9	20	10.3	8	15	18	11.2	3
92	24	11	6	14	5.4	12	20	16	11.8	1
88	12	13	15	20	3.2	4	25	18	11.5	1
84	5	19	16	24	5.4	7	35	19	10.9	1
80	14	47	40	64	10.7	5	60	31	10.5	2

NORTH-SOUTH COMPONENTS

100	-11	19	25	32	3.0	3	19	28	7.1	2
96	3	13	7	22	.6	8	9	19	1.5	3
92	3	10	7	12	17.8	8	18	13	1.4	1
88	- 3	10	10	13	17.6	6	13	13	1.2	2
84	- 7	13	13	13	20.4	7	5	15	10.0	7
80	- 1	30	30	39	22.7	5	21	33	8.6	3

METEOR WINDS OVER ATLANTA (34° N, 84° W)
FOR THE PERIOD APRIL 10, 1976 TO APRIL 12, 1976

EAST-WEST COMPONENTS

			24 Hour Component				12 Hour Component			
HEIGHT	MEAN	ER	AMP	ER	PHASE	ER	AMP	ER	PHASE	ER
100	1	17	6	26	3.8	14	7	21	8.5	7
96	- 8	16	17	24	9.5	5	25	24	6.9	1
92	-17	12	22	19	9.5	3	36	20	6.9	1
88	-22	12	20	17	9.1	3	38	19	7.1	1
84	-21	14	17	19	9.2	5	33	20	7.6	1
80	-12	18	21	28	10.8	5	27	27	8.8	2

NORTH-SOUTH COMPONENTS

100	-11	15	13	22	16.1	6	22	20	.4	2
96	-13	14	17	16	7.9	5	16	20	.5	2
92	-11	11	25	15	8.5	3	7	17	.2	4
88	- 9	12	26	15	9.4	3	5	16	8.4	6
84	- 9	12	23	16	9.0	3	13	18	7.9	2
80	-12	15	34	21	5.6	2	19	20	8.2	2

METEOR WINDS OVER ATLANTA (34° N, 84° W)
FOR THE PERIOD APRIL 19, 1976 TO APRIL 29, 1976

EAST-WEST COMPONENTS

			24 Hour Component				12 Hour Component			
HEIGHT	MEAN	ER	AMP	ER	PHASE	ER	AMP	ER	PHASE	ER
100	10	10	26	14	4.1	2	24	13	11.5	1
96	16	9	20	14	3.9	2	26	13	.8	1
92	21	7	7	11	3.1	5	23	10	1.4	1
88	24	7	7	10	16.7	6	16	10	2.1	1
84	24	8	13	12	15.5	3	14	12	2.8	2
80	19	10	11	16	12.7	4	20	13	2.5	1

NORTH-SOUTH COMPONENTS

100	-11	9	23	13	13.1	2	24	11	4.9	1
96	- 9	8	19	12	15.3	2	27	10	4.9	1
92	- 6	6	14	9	15.7	2	20	8	4.7	1
88	- 3	6	6	10	13.9	5	9	9	3.8	2
84	- 5	7	6	9	6.9	8	5	11	.2	4
80	-15	9	10	13	3.4	5	11	12	9.9	2

METEOR WINDS OVER ATLANTA (34° N, 84° W)
FOR THE PERIOD MAY 13, 1976 TO MAY 19, 1976

EAST-WEST COMPONENTS

			24 Hour Component				12 Hour Component			
HEIGHT	MEAN	ER	AMP	ER	PHASE	ER	AMP	ER	PHASE	ER
100	13	10	19	16	2.7	2	3	14	2.8	7
96	19	9	22	14	3.2	2	7	13	3.4	3
92	15	7	7	10	5.5	7	14	10	3.0	1
88	9	8	16	13	14.0	2	17	11	2.8	1
84	8	9	27	14	15.0	2	10	12	2.9	2
80	20	11	20	14	17.1	3	14	15	8.3	2

NORTH-SOUTH COMPONENTS

100	- 3	8	22	11	4.4	2	17	10	9.7	1
96	3	7	16	10	5.0	2	17	9	10.1	1
92	5	6	11	8	5.4	3	12	7	10.9	1
88	3	6	8	8	5.3	5	9	9	.9	2
84	1	7	9	10	4.8	4	14	11	2.6	1
80	- 1	8	16	11	4.5	3	19	12	3.4	1

METEOR WINDS OVER ATLANTA (34° N, 84° W)
FOR THE PERIOD MAY 25, 1976 TO MAY 31, 1976

EAST-WEST COMPONENTS

			24 Hour Component				12 Hour Component			
HEIGHT	MEAN	ER	AMP	ER	PHASE	ER	AMP	ER	PHASE	ER
100	5	23	11	27	8.7	9	18	28	6.2	3
96	11	14	20	16	5.7	4	19	19	6.6	2
92	22	12	13	15	7.9	5	16	17	5.6	2
88	32	13	17	19	13.3	4	21	18	4.1	1
84	33	15	24	21	15.3	3	31	23	3.5	1
80	20	19	18	28	20.2	5	31	28	3.2	1

NORTH-SOUTH COMPONENTS

100	- 7	23	8	41	2.3	9	4	31	7.1	8
96	- 2	12	10	15	6.1	7	8	16	3.8	4
92	6	9	6	11	8.3	8	16	12	3.5	1
88	12	10	6	15	11.9	7	22	12	3.7	1
84	12	11	12	17	11.3	5	24	15	4.2	1
80	1	14	29	20	9.3	2	27	18	5.2	1

METEOR WINDS OVER ATLANTA (34° N, 84° W)
FOR THE PERIOD JUNE 1, 1976 TO JUNE 11, 1976

EAST-WEST COMPONENTS

			24 Hour Components				12 Hour Component			
HEIGHT	MEAN	ER	AMP	ER	PHASE	ER	AMP	ER	PHASE	ER
100	8	29	46	36	3.7	4	31	38	11.8	3
96	- 8	15	34	20	1.7	3	36	24	1.0	1
92	- 3	11	15	18	22.1	4	27	18	2.3	1
88	11	10	29	15	16.0	2	27	14	4.4	1
84	22	13	53	19	15.0	1	39	18	5.7	1
80	18	16	58	24	15.0	2	37	26	6.7	1

NORTH-SOUTH COMPONENTS

100	2	28	33	26	.7	5	35	43	1.9	1
96	19	13	35	18	23.7	2	8	16	10.4	4
92	15	10	24	14	21.4	2	11	15	7.7	2
88	- 0	10	24	15	17.2	2	16	13	5.1	2
84	-16	13	32	20	14.5	2	32	18	3.9	1
80	-21	15	32	20	11.6	3	40	22	3.2	1

METEOR WINDS OVER ATLANTA (34° N, 84° W)
FOR THE PERIOD AUGUST 14, 1976 TO AUGUST 17, 1976

EAST-WEST COMPONENTS

			24 Hour Component				12 Hour Component			
HEIGHT	MEAN	ER	AMP	ER	PHASE	ER	AMP	ER	PHASE	ER
100	31	32	35	52	14.2	5	36	30	6.4	3
96	26	34	65	62	16.4	2	39	57	4.5	2
92	25	29	62	53	16.7	2	33	49	3.4	2
88	28	23	42	41	17.3	2	22	37	2.6	2
84	32	21	34	33	19.4	4	23	36	4.5	2
80	37	27	67	39	20.4	2	98	41	5.3	1

NORTH-SOUTH COMPONENTS

100	-18	30	47	49	6.3	3	74	49	10.5	1
96	-18	27	44	51	4.5	2	66	51	10.2	1
92	-28	24	60	40	2.4	2	53	40	9.8	1
88	-34	20	71	27	1.4	2	36	30	9.1	1
84	-23	20	53	25	.3	2	21	26	7.2	3
80	18	31	35	56	16.3	4	43	53	4.6	2

METEOR WINDS OVER ATLANTA (34° N, 84° W)
FOR THE PERIOD AUGUST 27, 1976 TO SEPTEMBER 3, 1976

EAST-WEST COMPONENTS

			24 Hour Component				12 Hour Component			
HEIGHT	MEAN	ER	AMP	ER	PHASE	ER	AMP	ER	PHASE	ER
100	53	25	9	35	9.2	14	38	36	8.2	2
96	40	21	21	29	11.2	6	49	31	7.7	1
92	23	17	12	22	10.6	8	44	24	7.1	1
88	10	16	11	24	3.1	8	35	23	6.4	1
84	6	18	25	26	2.6	4	24	26	6.1	2
80	20	20	32	30	4.5	3	20	28	8.3	3

NORTH-SOUTH COMPONENTS

100	-10	19	24	25	10.2	5	13	27	4.8	4
96	-13	18	30	23	10.7	4	8	28	6.3	5
92	- 3	14	24	19	9.8	3	15	21	5.8	2
88	11	13	20	18	8.0	4	25	18	5.2	1
84	21	15	24	21	7.4	4	31	21	4.5	1
80	20	18	39	24	9.1	3	32	27	3.0	1

METEOR WINDS OVER ATLANTA (34° N, 84° W)
FOR THE PERIOD SEPTEMBER 17, 1976 TO SEPTEMBER 28, 1976

EAST-WEST COMPONENTS

			24 Hour Component				12 Hour Component			
HEIGHT	MEAN	ER	AMP	ER	PHASE	ER	AMP	ER	PHASE	ER
100	17	23	25	34	23.3	5	20	31	11.4	3
96	6	20	16	25	18.6	7	46	28	8.0	1
92	7	16	19	22	5.2	5	72	24	7.3	1
88	11	18	58	26	5.1	2	73	25	6.9	1
84	5	22	60	34	5.0	2	39	31	6.7	1
80	-19	36	18	62	17.4	7	44	49	11.9	2

NORTH-SOUTH COMPONENTS

100	8	20	34	31	2.1	3	28	28	11.9	2
96	2	16	28	23	.8	3	7	23	.5	7
92	- 4	14	12	19	22.9	6	10	20	2.1	4
88	- 7	14	9	20	15	8	20	20	1.8	2
84	- 4	16	13	21	12.2	7	26	22	1.4	2
80	8	21	18	30	5.7	6	18	31	.9	3

METEOR WINDS OVER ATLANTA (34° N, 84° W)
FOR THE PERIOD OCTOBER 11, 1976 TO OCTOBER 23, 1976

EAST-WEST COMPONENTS

			24 Hour Component				12 Hour Component			
HEIGHT	MEAN	ER	AMP	ER	PHASE	ER	AMP	ER	PHASE	ER
100	13	24	72	42	12.0	1	60	32	11	1
96	22	22	26	36	12.0	3	60	30	11.4	1
92	17	18	33	30	1.2	2	28	26	11.9	1
88	8	19	81	32	1.0	1	24	21	3.4	2
84	4	21	94	35	1.0	1	56	24	3.6	1
80	13	27	48	44	.5	2	87	33	2.6	1

NORTH-SOUTH COMPONENTS

100	2	20	21	33	1.5	4	29	23	2.9	1
96	13	18	12	21	7.9	10	25	23	2.1	2
92	13	15	17	17	7.9	6	21	20	1.9	2
88	10	17	19	20	5.1	6	17	22	2.3	2
84	15	17	31	28	2.7	2	15	21	3.0	3
80	37	21	45	34	1.5	2	13	27	3.3	4

METEOR WINDS OVER ATLANTA (34° N, 84° W)
FOR THE PERIOD NOVEMBER 8, 1976 TO NOVEMBER 15, 1976

EAST-WEST COMPONENTS

			24 Hour Component				12 Hour Component			
HEIGHT	MEAN	ER	AMP	ER	PHASE	ER	AMP	ER	PHASE	ER
100	- 6	22	65	33	8.4	2	68	38	1.2	1
96	- 6	17	29	24	7.8	3	23	23	11.7	2
92	-12	15	16	21	5.4	5	22	20	9.9	2
88	-15	16	10	24	3.7	9	21	21	9.3	2
84	- 3	20	14	30	15.5	7	24	30	8.1	2
80	34	26	70	38	15.4	2	56	39	7.3	1

NORTH-SOUTH COMPONENTS

100	3	20	10	24	10.1	13	21	25	2.3	3
96	5	14	26	21	15.6	3	35	20	4.8	1
92	10	12	33	19	15.5	2	35	17	5.2	1
88	12	13	28	19	15.0	2	24	18	5.7	1
84	9	14	18	21	15.7	4	24	22	6.6	1
80	- 5	17	25	23	19.5	4	50	25	6.6	1

METEOR WINDS OVER ATLANTA (34° N, 84° W)
FOR THE PERIOD NOVEMBER 16, 1976 TO NOVEMBER 25, 1976

EAST-WEST COMPONENTS

			24 Hour Component				12 Hour Component			
HEIGHT	MEAN	ER	AMP	ER	PHASE	ER	AMP	ER	PHASE	ER
100	- 1	19	30	29	18.0	3	6	26	5.0	9
96	1	18	15	27	19.3	6	13	26	.3	4
92	14	14	14	21	18.7	5	6	21	1.9	6
88	29	13	20	18	17.5	4	19	18	4.8	2
84	35	15	20	21	17.4	4	31	21	4.7	1
80	21	18	8	27	21.6	12	30	27	3.4	2

NORTH-SOUTH COMPONENTS

100	20	15	32	20	23.7	3	17	21	2.4	1
96	23	13	30	18	21.4	2	22	18	4.8	2
92	19	11	17	15	20.3	4	18	15	4.1	2
88	13	11	3	16	13.6	18	24	15	2.0	1
84	8	12	9	18	9.4	7	37	16	1.3	1
80	10	14	8	20	19.9	10	30	21	1.4	1

METEOR WINDS OVER ATLANTA (34° N, 84° W)
FOR THE PERIOD NOVEMBER 26, 1976 TO DECEMBER 2, 1976

EAST-WEST COMPONENTS

			24 Hour Component				12 Hour Component			
HEIGHT	MEAN	ER	AMP	ER	PHASE	ER	AMP	ER	PHASE	ER
100	65	26	89	42	16.3	1	83	40	2.7	1
96	62	19	94	26	16.7	1	71	26	3.1	1
92	39	16	55	22	16.9	2	44	22	2.8	1
88	9	19	2	24	18.1	49	25	28	1.3	2
84	-15	23	34	29	5.5	4	28	30	12.0	2
80	-22	23	27	29	7.5	5	19	32	1.1	3

NORTH-SOUTH COMPONENTS

100	31	24	79	40	15.4	1	45	28	.5	1
96	23	18	67	25	15.9	1	25	24	.4	2
92	17	15	35	19	16.9	2	22	20	.3	2
88	12	17	14	23	22.8	6	26	22	.4	2
84	10	19	25	31	2.2	3	27	25	.5	2
80	10	19	7	26	4.7	15	17	27	.7	3

METEOR WINDS OVER ATLANTA (34° N, 84° W)
FOR THE PERIOD DECEMBER 3, 1976 TO DECEMBER 10, 1976

EAST-WEST COMPONENTS

			24 Hour Component				12 Hour Component			
HEIGHT	MEAN	ER	AMP	ER	PHASE	ER	AMP	ER	PHASE	ER
100	56	21	68	30	10.3	2	45	30	4.3	1
96	43	18	66	27	11.0	1	38	25	4.8	1
92	30	16	44	24	10.2	2	26	22	5.2	2
88	20	15	29	20	7.4	3	14	21	5.8	3
84	15	17	26	21	6.0	4	8	23	5.8	6
80	18	21	30	33	11.3	3	17	29	4.6	3

NORTH-SOUTH COMPONENTS

100	-12	18	47	26	23.2	2	48	26	5.7	1
96	-27	15	53	22	.9	2	39	23	5.6	1
92	-20	13	54	18	1.9	1	35	18	4.9	1
88	- 1	12	47	18	2.6	1	37	17	4.0	1
84	17	13	33	19	3.5	2	35	18	3.4	1
80	22	17	15	21	6.1	7	15	24	2.6	3

METEOR WINDS OVER ATLANTA (34° N, 84° W)
FOR THE PERIOD DECEMBER 11,1976 TO DECEMBER 17, 1976

EAST-WEST COMPONENTS

			24 Hour Component				12 Hour Component			
HEIGHT	MEAN	ER	AMP	ER	PHASE	ER	AMP	ER	PHASE	ER
100	- 3	17	22	25	9.1	4	19	23	4.5	3
96	- 4	16	14	22	5.2	6	22	24	8.1	2
92	- 7	13	18	19	4.9	4	23	21	7.9	1
88	- 8	14	23	20	5.5	4	16	21	6.0	2
84	- 1	15	30	22	4.9	3	26	20	4.0	2
80	17	19	49	27	3.0	2	36	27	2.9	1

NORTH-SOUTH COMPONENTS

100	33	14	11	20	1.8	7	7	21	7.4	5
96	33	14	11	20	2.3	6	19	20	7.0	2
92	27	12	3	17	22.9	18	13	16	5.9	2
88	18	12	15	18	15.9	4	12	17	3.3	3
84	8	13	33	19	15.1	2	12	19	1.7	3
80	1	16	50	24	14.4	2	21	21	9.7	2

METEOR WINDS OVER ATLANTA (34° N, 84° W)
FOR THE PERIOD DECEMBER 18, 1976 TO DECEMBER 24, 1976

EAST-WEST COMPONENTS

			24 Hour Component				12 Hour Component			
HEIGHT	MEAN	ER	AMP	ER	PHASE	ER	AMP	ER	PHASE	ER
100	- 7	18	25	26	21.8	4	11	28	3.0	4
96	- 5	16	29	24	23.4	3	30	20	5.0	2
92	- 7	13	30	20	1.2	2	29	16	5.1	1
88	-12	13	37	21	2.6	2	13	17	5.3	3
84	-15	15	47	24	2.9	2	9	20	9.4	5
80	-16	24	61	32	2.0	2	27	33	9.3	2

NORTH-SOUTH COMPONENTS

100	7	16	14	25	11.7	6	30	24	.5	1
96	20	14	8	22	12.6	9	14	23	1.6	2
92	22	11	6	17	21.0	12	15	16	3.9	2
88	17	11	19	17	22.7	3	18	15	4.7	2
84	11	13	29	19	23.1	2	7	18	6.1	5
80	10	16	31	25	23.4	3	34	23	10.3	1

METEOR WINDS OVER ATLANTA (34° N, 84° W)
FOR THE PERIOD DECEMBER 25, 1976 TO DECEMBER 31, 1976

EAST-WEST COMPONENTS

			24 Hour Component				12 Hour Component			
HEIGHT	MEAN	ER	AMP	ER	PHASE	ER	AMP	ER	PHASE	ER
100	- 0	19	11	27	14.1	9	27	28	6.2	2
96	20	17	8	23	6.2	12	5	25	7.8	8
92	45	16	24	21	4.3	4	18	22	11.6	2
88	57	18	32	23	4.5	3	24	25	12.0	2
84	41	20	29	27	7.1	4	6	31	2.1	9
80	-19	31	63	56	11.4	2	60	48	5.5	1

NORTH-SOUTH COMPONENTS

100	17	17	7	23	21.3	14	34	23	5.7	1
96	25	17	12	25	23.0	7	31	22	4.0	1
92	27	19	37	31	23.5	2	39	25	1.7	1
88	23	24	58	40	23.4	2	59	34	.7	1
84	9	23	52	38	23	2	53	34	.2	1
80	-18	32	22	40	16.0	9	18	41	7.7	4

METEOR WINDS OVER ATLANTA (34° N, 84° W)

August 1974 - February 1976

by

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Georgia Institute of Technology
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Presented at the Third European Geophysical Society Meeting, Amsterdam, September 7-10, 1976.

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ABSTRACT

An all sky, continuous wave radio meteor wind facility has been operated in Atlanta by the Georgia Institute of Technology under National Science Foundation sponsorship. A double sideband suppressed carrier CW transmitter, operates on 32.5 MHz ± 360 Hz, with an RMS output of 2 KW, on the Georgia Tech campus; the receiving site is at Technology Park/Atlanta, 27 kilometers northeast of the campus. Height/time profiles of mean wind circulation, a two day period "planetary wave", and tides between 80 and 100 kilometers, measured from August 1974 to February 1976 are presented.

INTRODUCTION

The Georgia Tech Radio Meteor Wind Facility which has been in continuous operation since August 9, 1974, is described in detail in Roper (1975). Individual meteor wind dopplers are measured to an accuracy of 3 m/sec, and reflection center heights to ± 2 km. This resolution is ample for the determination of the prevailing and tidal wind observations presented here. Winds are determined by matching the measured line of sight drifts to a model, using the analysis of Groves (1959). Details of the technique are given in Roper (1975).

RESULTS

The results of continuous measurements made from August 9, 1974 through February 1976, less six weeks in April/May, appear in Figures 1 through 4. Only a preliminary assessment of the significance of these results, with particular emphasis on the stratwarm period of January 1 through 17, 1975, is presented here. A more detailed evaluation will eventually be published elsewhere.

In analyzing the raw data, mean values of the prevailing wind, 48, 24, and 12 hour components were extracted over 5 to 20 day intervals, the longer intervals being analyzed when useable echo rates were down. The two day period was extracted simply because it has been noticed on odd occasions at other meteor wind stations, particularly in January data, and was considered as a possible indicator of "planetary wave" penetration into the meteor region from below.

The zonal component of the prevailing wind (the "constant" term in the Fourier series best fitting the data over each interval analyzed) for the nineteen months August 74 - February 76 is shown in Figure 1. The predominantly easterly flow (wind vector directed toward the west) August 74 through January 75 is unexpected. Barnes (1973), for somewhat higher northern latitudes, reports summer and winter westerlies, with equinoctial easterlies, while Elford (1974), for Adelaide, Australia (35° S, 139° E), reports predominant zonal westerlies, maximizing in summer and winter. There is some intriguing structure in the flow - an easing of the easterly flow, with a weak reversal, in late December 74, a return to easterlies in January 75, and then a rapid switch to westerlies in February 75. It is tempting to associate this sequence of changes in December through February with the polar stratwarm of December 15 through February 15 report by Quiroz et al (1975), and regarded as a major warming January 1 through 17.

In January 76, and again in February 76, there are weak reversals of the more usual winter westerlies associated with a "minor" and an "early" warming respectively.

The meridional flow is characterized by generally lower wind speeds, and an indication of a change from northerly flow in summer to southerly flow in winter (in keeping with a warm winter pole at meteor altitudes) with some structure in December-January.

Figure 2 shows zonal and meridional height time profiles of the amplitude of the 48 hour component. Greatest amplitudes, associated with maximum rates of change of amplitude with both height and time, occur in late December 74 - early January 75, and in late February 76. A large amplitude long lived wave is present in the zonal flow in August - September 75.

The diurnal (24 hour) component amplitudes appear irregular, showing considerable structure in both zonal and meridional components in December 74-January 75, and January - February 76.

The semidiurnal (12 hour) component amplitude variations are even more complex. However there is a minimum in both zonal and meridional amplitudes in late December 74, early January 75. This may not be significant (at least in association with the major stratwarm), since the behavior is similar in December 75 - January 76.

CONCLUSIONS

This very preliminary assessment of nineteen months of radio meteor winds measured over Atlanta (34° N, 84° W) demonstrates that continuous recording of radio meteor wind data reveals week by week variations in prevailing, possible planetary wave, diurnal and semidiurnal components which may be able to be directly related to the meteorology of the atmosphere below. In particular, this set of data shows intriguing structure in wind patterns measured over the period of the stratwarm of January 1 - 17, 1975.

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Barnes, Arnold A., Jr., "Status report on radar meteor wind and density measurements", Bull. Amer. Meteorol. Soc., 54, 900-910, 1973.

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Groves, G. V., "A theory for determining upper atmosphere winds from radio observations on meteor trails", J. Atmos. Terr. Phys., 16, 344-356, 1959.

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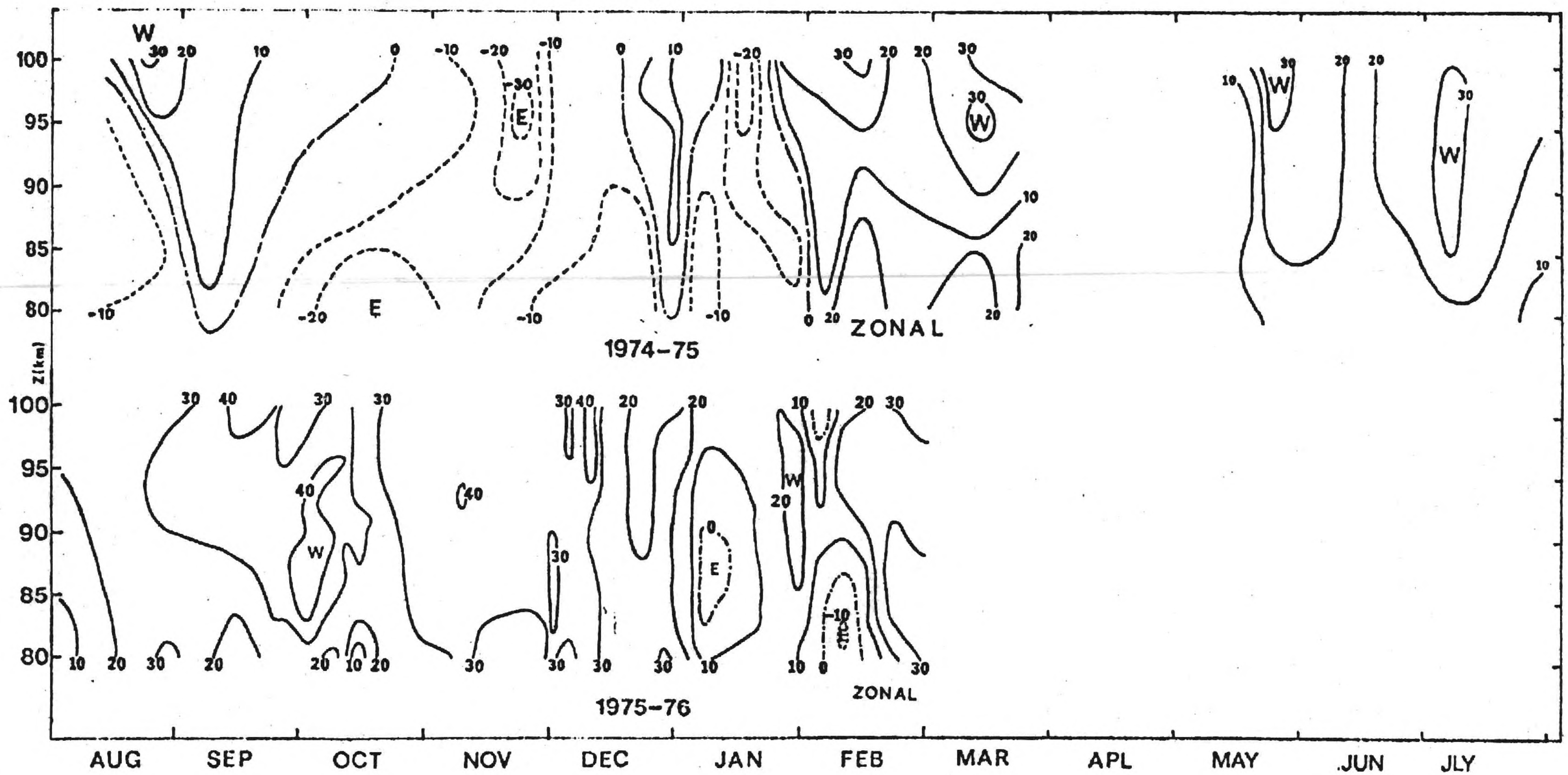
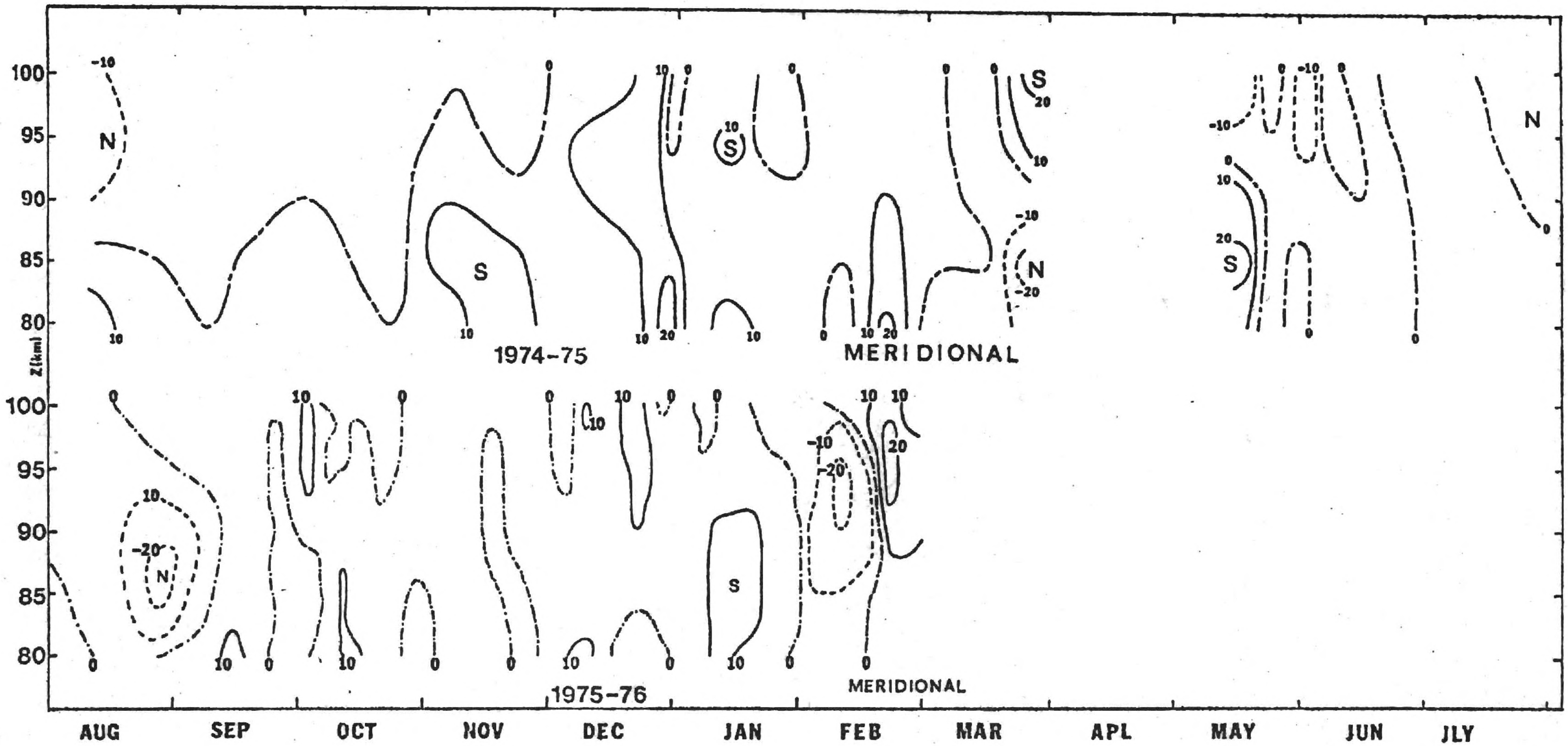
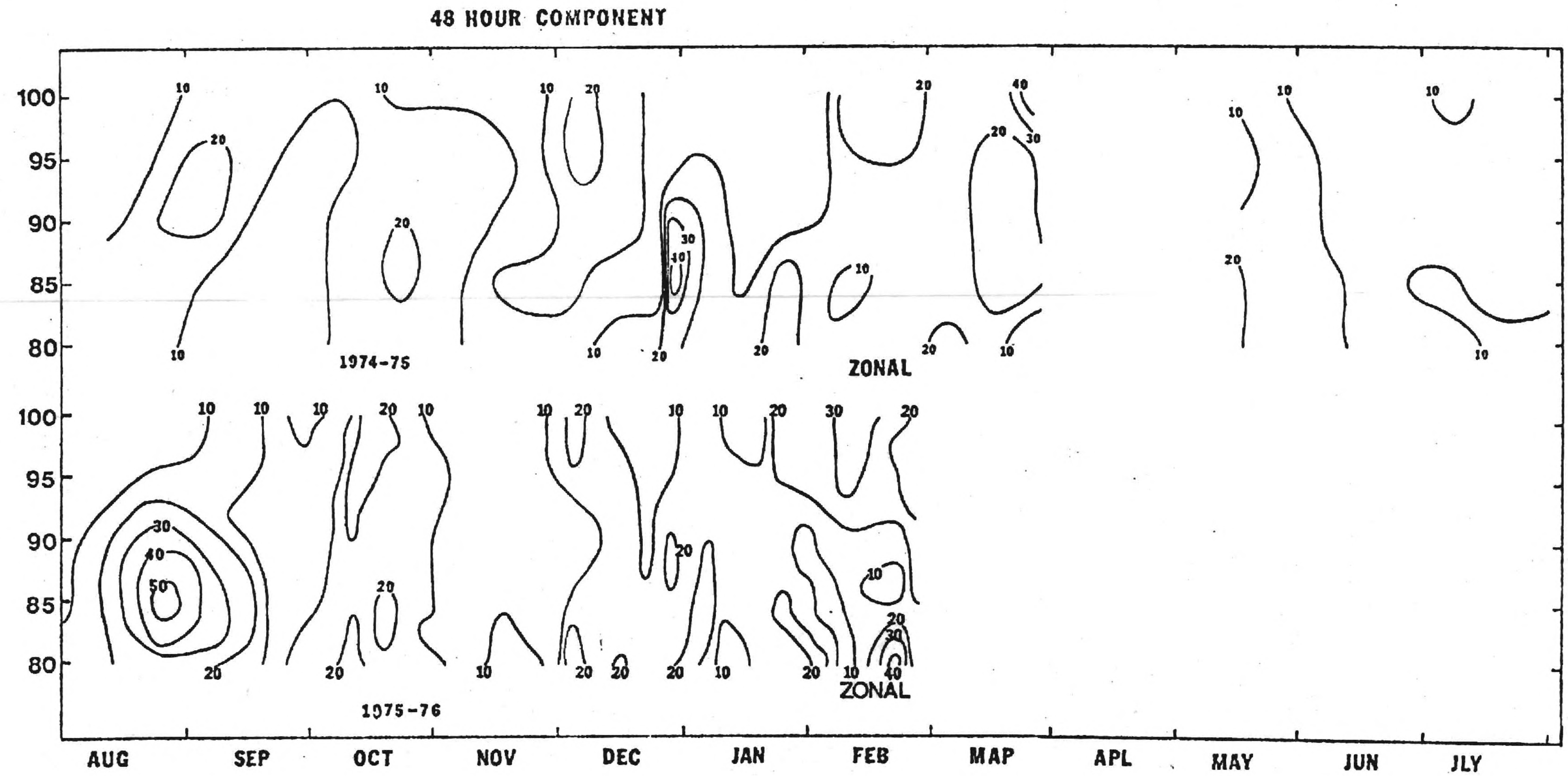
Roper, R. G., "The measurement of meteor winds over Atlanta (34° N, 84° W)", Radio Sci., 10, 363-369, 1975.

PREVAILING WIND



PREVAILING WIND

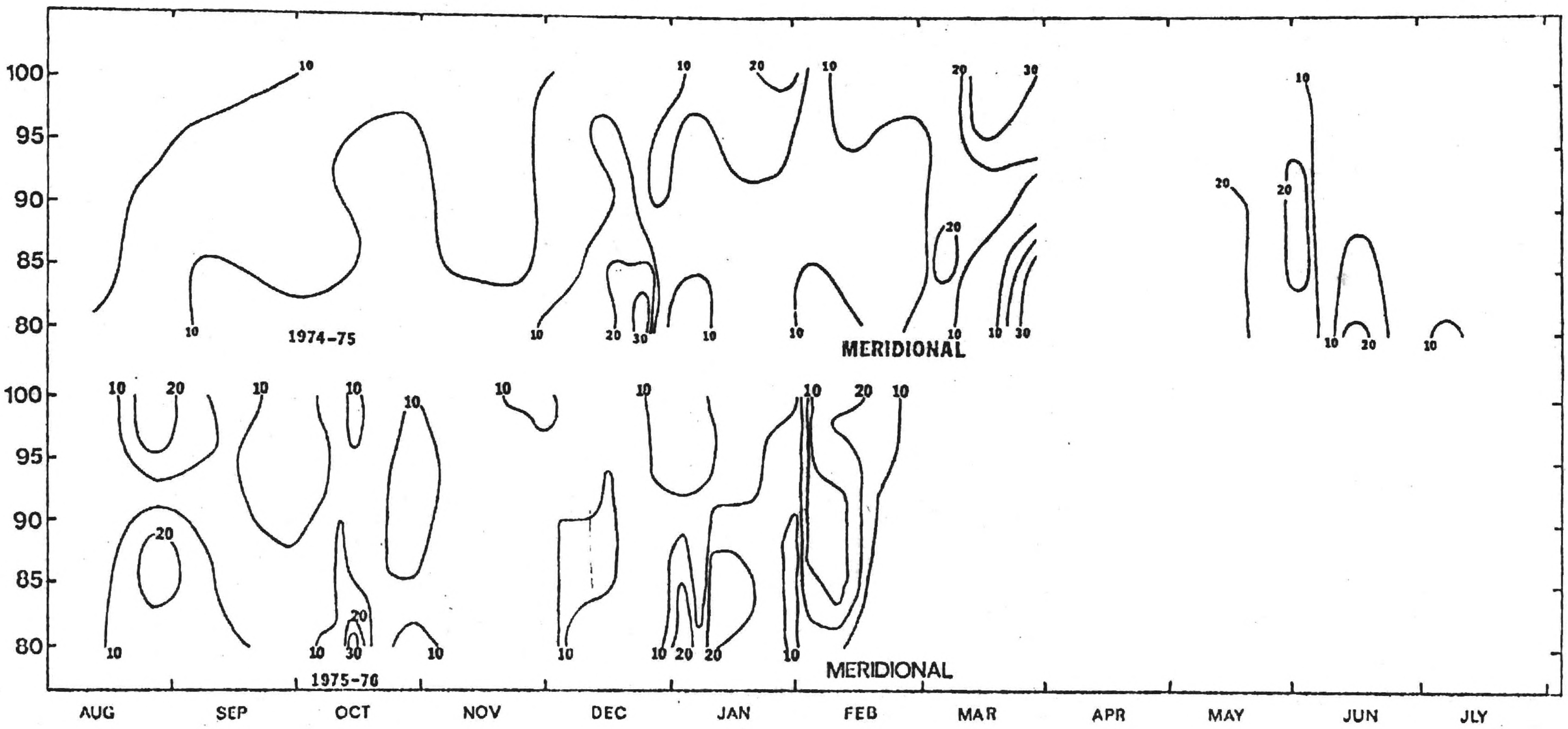




48 HOUR COMPONENT
1974-75
ZONAL
1975-76
ZONAL
AUG
SEP
OCT
NOV
DEC
JAN
FEB
MAP
APL
MAY
JUN
JLY

A-7

48 HOUR COMPONENT



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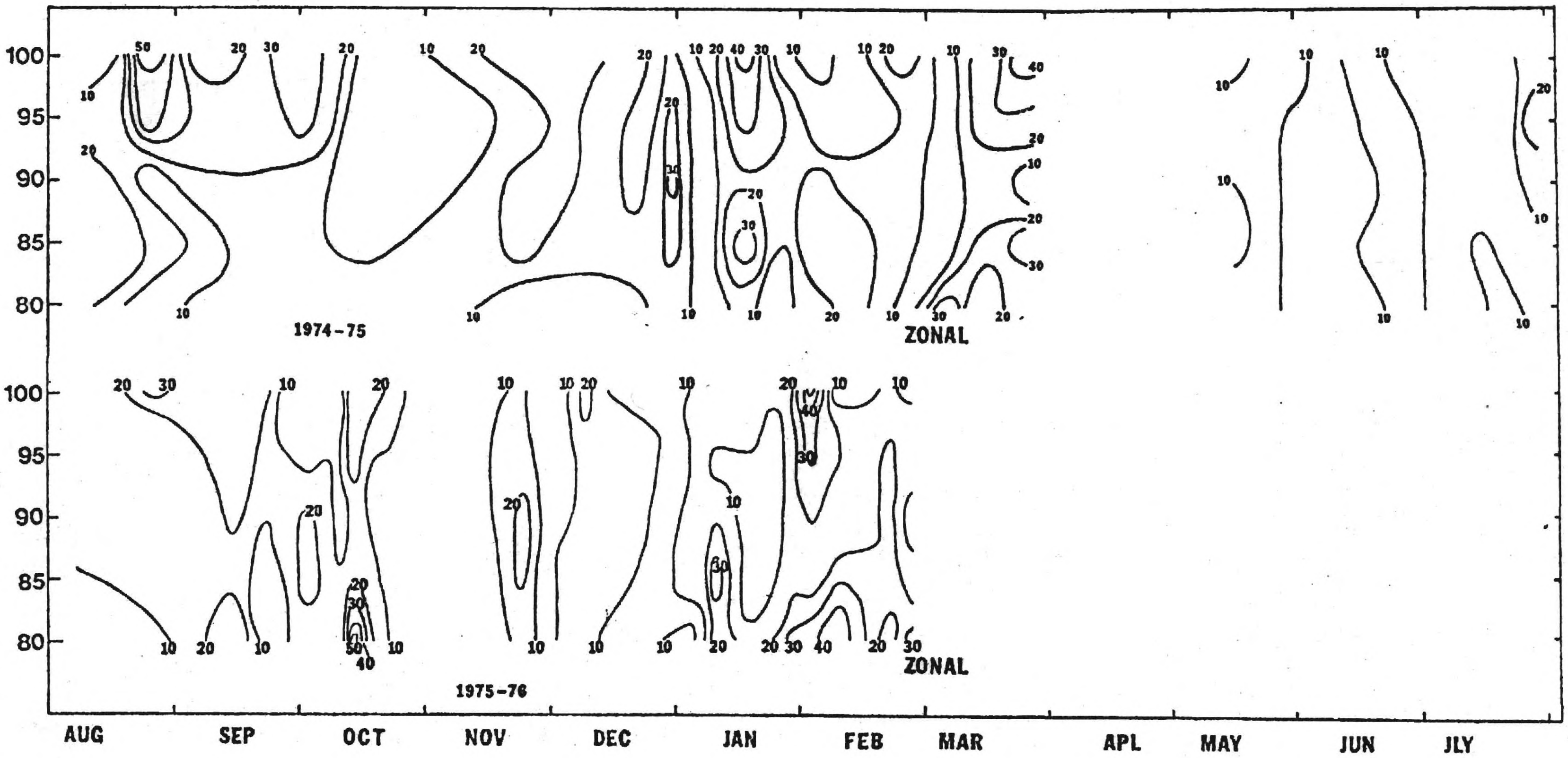

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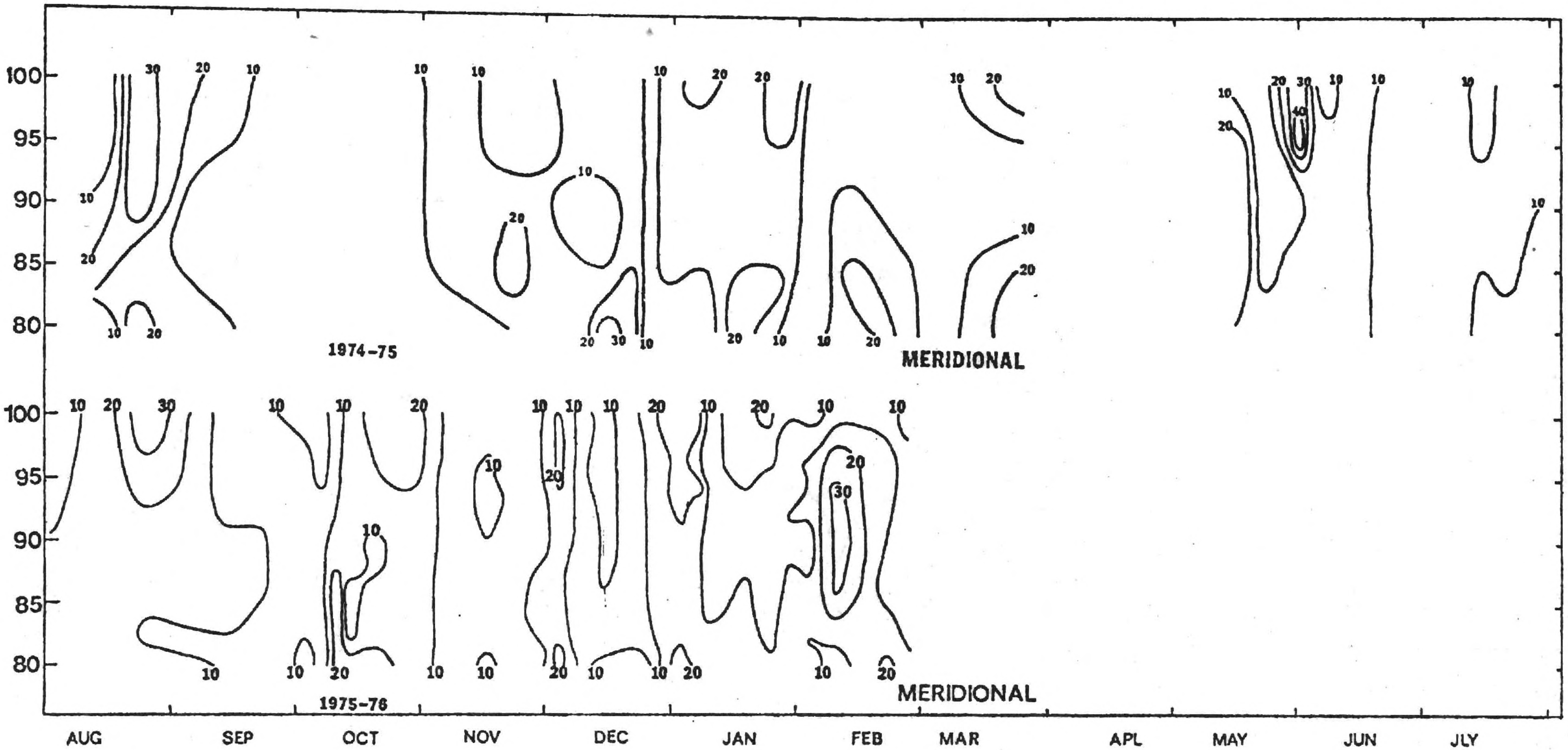
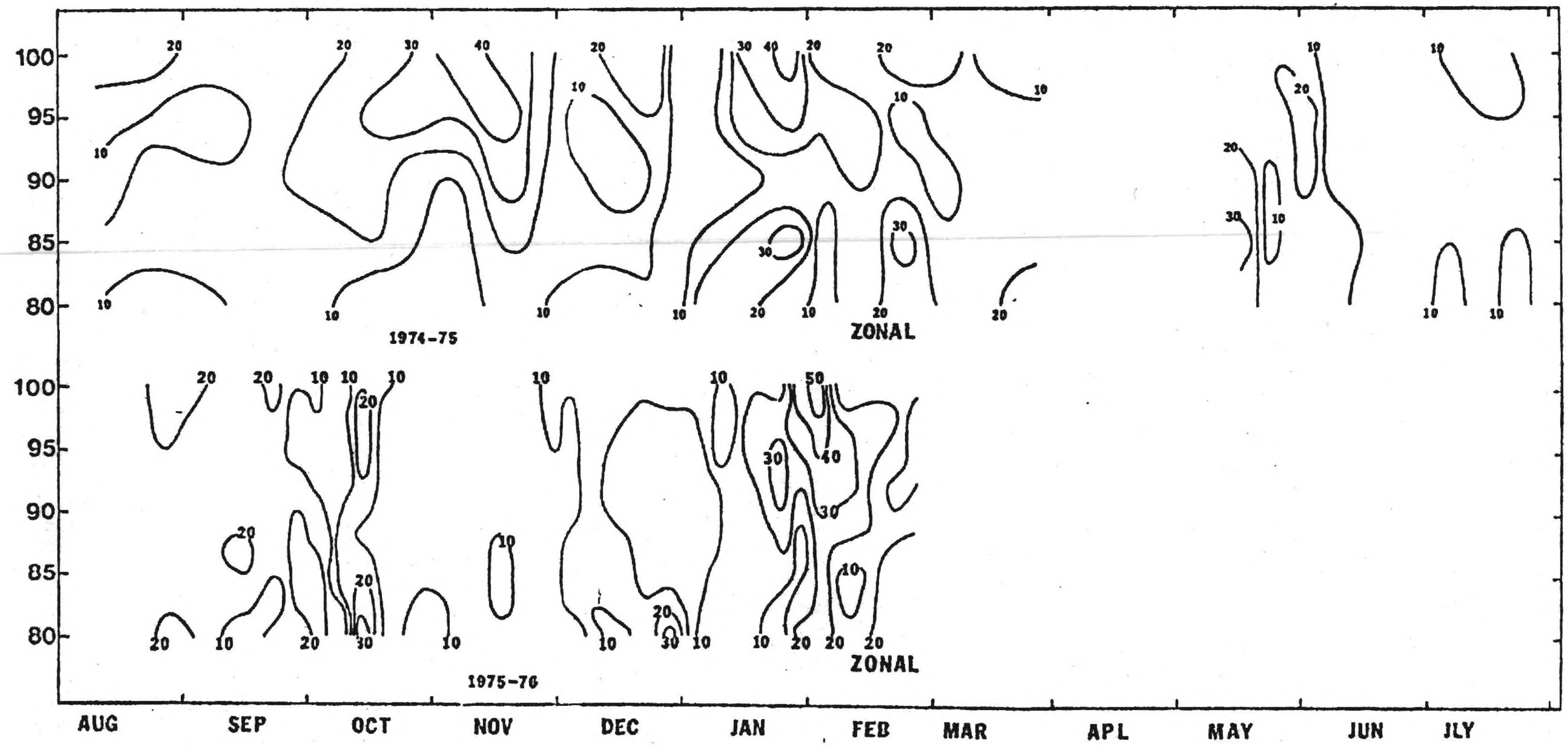


12 HOUR COMPONENT



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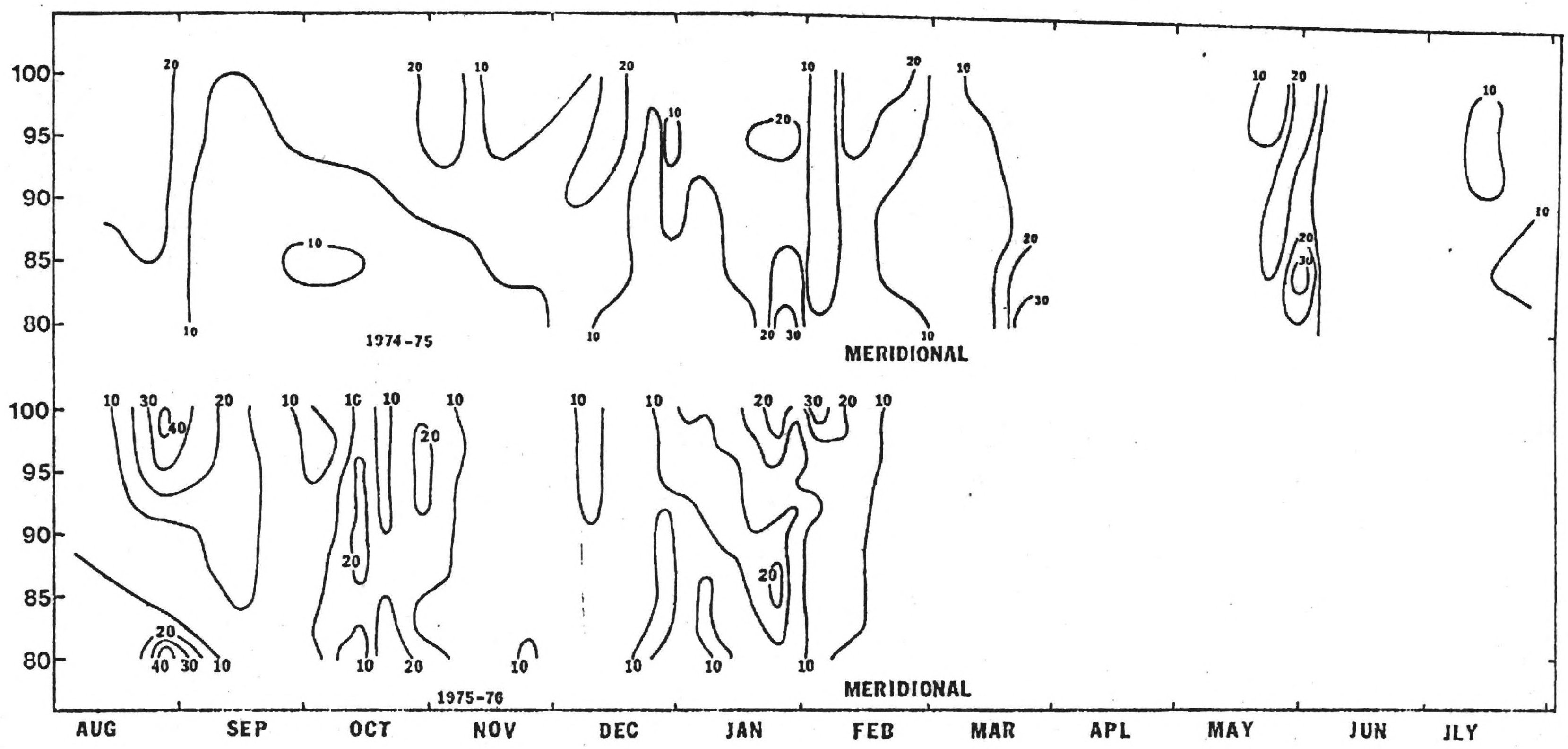

E-16-668
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FINAL PROJECT REPORT
NSF FORM 98A

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PART I—PROJECT IDENTIFICATION INFORMATION

1. Institution and Address	2. NSF Program	3. NSF Award Number
Georgia Institute of Technology School of Aerospace Engineering Atlanta, GA 30332	Atmospheric Research (Aeronomy)	ATM75-14414
	4. Award Period From 6/1/75 To 5/31/78	5. Cumulative Award Amount $90,600

6. Project Title

"MEASUREMENT OF RADIO METEOR WINDS OVER ATLANTA (34° N, 84° W)

PART II—SUMMARY OF COMPLETED PROJECT *(FOR PUBLIC USE)*

During the period of this grant, the Georgia Tech Radio Meteor Wind Facility has continued to measure winds in the upper atmosphere at the mesopause level (80 to 100 km altitude) over Atlanta (34° N, 84° W). Of particular interest has been an investigation of "Planetary Waves in the Upper Atmosphere", the subject of a Ph.D. thesis written by M. L. Salby, and of the effects of polar winter stratospheric warming events on the mesopause level winds over Atlanta, the subject of an almost completed Ph.D. thesis by P. M. Dolas. For many years a planetary wave with a two day period has been observed globally by radio meteor wind stations, but an explanation of its origin has previously been lacking. It has now been established that the wave is forced from the atmosphere below. The discovery that polar stratwarms have an appreciable effect on the mesopause level winds at midlatitudes, and that, in fact, these changes in the wind field occur before the polar warmings, has added considerably to our understanding of the dynamics of the upper atmosphere, and bears directly on the problems of ozone formation and transportation.

In conjunction with data gathered by the International Association of Geomagnetism and Aeronomy Global Radio Meteor Wind Studies Project (of which the principal investigator is international coordinator), the Atlanta results have shown that below 85 km the winds are part of a distinct mesospheric circulation, while above, the winds are thermospheric. This emphasizes the need to extend global atmospheric circulation models which include the mesosphere to at least as high as 85 km altitude.

PART III—TECHNICAL INFORMATION *(FOR PROGRAM MANAGEMENT USES)*

1. ITEM *(Check appropriate blocks)*	NONE	ATTACHED	PREVIOUSLY FURNISHED	TO BE FURNISHED SEPARATELY TO PROGRAM: Check (✓)	Approx. Date
a. Abstracts of Theses		X			
b. Publication Citations		X			
c. Data on Scientific Collaborators		X			
d. Information on Inventions	X				
e. Technical Description of Project and Results					
f. Other *(specify)*					

2. Principal Investigator/Project Director Name *(Typed)*	3. Principal Investigator/Project Director Signature	4. Date
Dr. R. G. Roper		11/29/78

Publications

Open literature:

1. "Winds from the Atlanta (34° N, 84° W) Radio Meteor Wind Facility", J. Atmos. Terrest. Phys., 40, 899, 1978.

2. "A Comparison of Radio Meteor and Airglow Winds", with G. Hernandez, Advances in Earth and Planetary Sciences, 7, 1978 (in press).

   Reprints will be forwarded as soon as received.

Conference Proceedings:

1. "A Comparison of Radio Meteor and Airglow Winds", with G. Hernandez, IAMAP Proceedings, Joint Assembly with IAGA, Seattle, August, 1977 (see open literature).

2. "The Effect of Polar Stratwarms on the Winds at the Mesopause Level in Mid Latitudes", Proceedings of the 18th Amer. Meteorol. Soc. Radar Meteorol. Conf., Atlanta, GA, March, 1978. (bound in the back of Final Technical Report)

Theses:

"Planetary Waves in the Upper Atmosphere", by M. L. Salby, Ph.D. Thesis, Georgia Institute of Technology, April, 1978. (abstract bound in Final Technical Report)

Reports:

"Radio Meteor Winds Measured over Atlanta (34° N, 84° W) August 1974 - December 1976", Interim Report on Contract E-16-648, NSF Grant No. ATM75-14414, May, 1977.

"Radio Meteor Winds Measured over Atlanta (34° N, 84° W) August 1974 - December 1977, Final Technical Report on Contract E-16-668, NSF Grant No. ATM75-14414, July, 1978.

Data on Scientific Collaborators

Graduate Students

M. L. Salby
Ph.D. awarded April 1978

P. M. Dolas
Ph.D. thesis defence scheduled for December 20, 1978